



TBEP Technical Report

#20-25

September 2025

Nursery-based restoration of *Thalassia testudinum* using beach-cast seedlings:

Lessons learned and Recommendations from Wolf Branch, Tampa Bay, Florida

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Introduction

Seagrass loss has been a topic of increasing concern worldwide (Orth et al. 2006, van Katwijk et al. 2016). The state of Florida has experienced significant seagrass declines (30%-80% in some areas) due to a variety of anthropogenic threats (development, poor water quality, scarring, etc.) (Sargent et al. 1995, Yarbro & Carlson Jr 2016). Seagrass beds provide numerous ecosystem services including sediment stabilization, nursery habitat, nutrient and carbon cycling, among others (Costanza et al. 1997, Tussenbroek et al. 2006, Duarte et al. 2010). Florida is home to eight out of the 10 species found in the Tropical Atlantic Bioregion, including *Thalassia testudinum*, *Halodule wrightii*, *Syringodium filiforme*, *Ruppia maritima*, *Halophila engelmannii*, *Halophila decipiens*, *Halophila ovalis*, and *Halophila stipulacea* (Short et al. 2007, Waycott et al. 2021, Campbell et al. 2025).

The seagrass *T. testudinum* is a robust, slow-growing species that often acts as the climax species in Atlantic tropical and sub-tropical seagrass succession (Dawes & Meads 2009). It is usually the dominant seagrass in south Florida and is often heavily impacted by poor water quality and other anthropogenic effects (Yarbro & Carlson Jr 2016). Because of its slow growth and environmental requirements, active restoration of formerly *Thalassia*-dominated beds has often focused on faster-growing, colonizing species such as *H. wrightii*, with the goal of starting and compressing succession (Kenworthy et al. 2018). Projects have historically involved removing plants from a donor bed and replanting them at a recipient site, often with varying degrees of success (Rezek et al. 2019). However, it may be possible to develop restoration strategies with minimal or no impact to preexisting seagrass beds.

Seed-based seagrass restoration is increasingly used in temperate systems to restore and replenish seagrass beds (Balestri & Lardicci 2012, Li et al. 2021, Tan et al. 2023). *T. testudinum* is dioecious and reproduces both asexually and sexually, with female plants developing fruits that contain one to six viviparous seeds (Tussenbroek et al. 2006). Dispersal of *T. testudinum* propagules can range 1,000s of km, and each year large numbers of them can be found in the wrack lines of Florida's Gulf and Atlantic coast beaches (Lewis III & Phillips 1980). By using *T. testudinum* seedlings that have washed ashore, it is possible to jumpstart recovery of seagrass beds without damaging extant beds. Shore-cast seedlings represent wasted reproductive effort but with

intervention can become a nondestructive method of seagrass restoration, either alone, to establish *T. testudinum* beds, as tested in Tampa Bay, or in conjunction with more traditional *Halodule*-focused efforts (Durako & Moffler 1987).

The following report details different techniques and methods to locate, grow and outplant *Thalassia testudinum* seedlings. This paper will help inform scientific researchers and managers about different aspects of *T. testudinum* cultivation and the potential for seedling-based restoration. We hope these methods will assist in the development of sustainable seagrass restoration techniques.

***T. testudinum* Seedling Collection**

Prior to collection, all necessary permits should be obtained. The Florida Fish and Wildlife Conservation Commission requires a [Special Activity License](#) for the collection of marine vegetation, including *T. testudinum* seedlings. If you wish to collect from a State Park or Aquatic Preserve, you will also need an [Environmental Resource Permit](#) from the Florida Department of Environmental Protection. Ensure that you have all required permits before collecting.

Seedling Collection Site Selection

There are several criteria that should be considered when selecting a seagrass seed collection site. Locations must be accessible by vehicle for ease of access. Because large areas of the coastline will need to be surveyed in a limited number of days, we recommend choosing sites accessible by vehicle rather than by boat. Examples of targeted sites would be public beaches, parks, and causeways adjacent to stable *T. testudinum* meadows. Confirm that the potential site has public access, or if on private property, gain permission from the property owners before visiting. Sites can be evaluated using aerial or satellite imagery to identify beach areas near seagrass beds. For example, Google Earth is a great resource to determine if your potential site has seagrasses nearby (Figure 1). Seagrass can be identified by dark signatures in the water; however, it is sometimes difficult to distinguish between macroalgae, rocks and reef, or to see through turbid water. You can confirm seagrass presence with seagrass maps available online (e.g., <https://geodata.myfwc.com/datasets/myfwc::seagrass-habitat-in-florida/about>) or visit the site before collection begins.



Figure 1: A Google Earth image of a potential seedling site. Red dots indicate shorelines that can be searched by foot for seedlings.

Upon arriving at a potential collection site, the first thing to look for is seagrass wrack onshore (Figure 2). Wrack can be an indicator of seagrass presence and/or connectivity to your collection site. Be aware that some public beaches remove/bury wrack by hand or heavy machinery. If this is the case either plan to search early in the morning before the beaches are cleaned or check for large piles where the scraped product has been dumped. If the wrack contains *T. testudinum* blades, then it is likely that a nearby seagrass bed contains *T. testudinum*. If dead blades are washing onshore from a nearby seagrass bed, then fruits and seedlings will too. Check to see if the wrack is fresh; i.e., green. Older wrack may indicate that the site experiences low water flow and influx of new materials may occur more rarely. It is difficult to predict the type of current and wave action a site may have prior to visiting. Areas with large tidal ranges and low wave action are optimal for finding fresh seedlings.

Seedling Collection

The greatest challenge and limiting factor in *T. testudinum* seedling collection is time. The species has a small window once a year for sexual reproduction. *T. testudinum* will release seedlings annually from July to August (Durako & Moffler 1987). We have found that the southern region of Florida typically produces seedlings first, starting in early July, and the northern half of the state begins to seed in early August. It can be difficult to pinpoint exactly when certain locations will begin producing so it is important to have a general idea and to check your sites frequently.

Once *T. testudinum* seedlings start appearing there is limited time to collect. The length of time that seedlings will be found onshore is dependent on several factors, including the size and productivity of the seagrass bed, tidal cycles and external factors such as tropical storms and hurricanes that can damage grassbeds and accelerate the rate that fruits and seedlings are released (Congdon et al. 2019). Seedling yield will vary widely by site and year, so check multiple sites per day to maximize seedling collection potential.



Figure 2: Cocoplum Beach in Marathon, Florida. Seedlings and fruits were collected in the wrack between the water and high tide line.

Seedlings and fruits can be found both on the shore or in the shallow nearshore area (Figure 2). This guide focuses on the collection of shore-cast seedlings as salvage material for restoration; therefore, we do not recommend collecting seedlings from seagrass beds where sexual recruitment may be important for meadow maintenance. Pay particular attention to areas where small particulate detritus and debris collects. Seedlings can be found washed ashore from the low to high tide lines and may be tangled in or underneath piles of wrack. Fruits will often be found floating in the water or sitting on top of wrack lines (Figure 3).

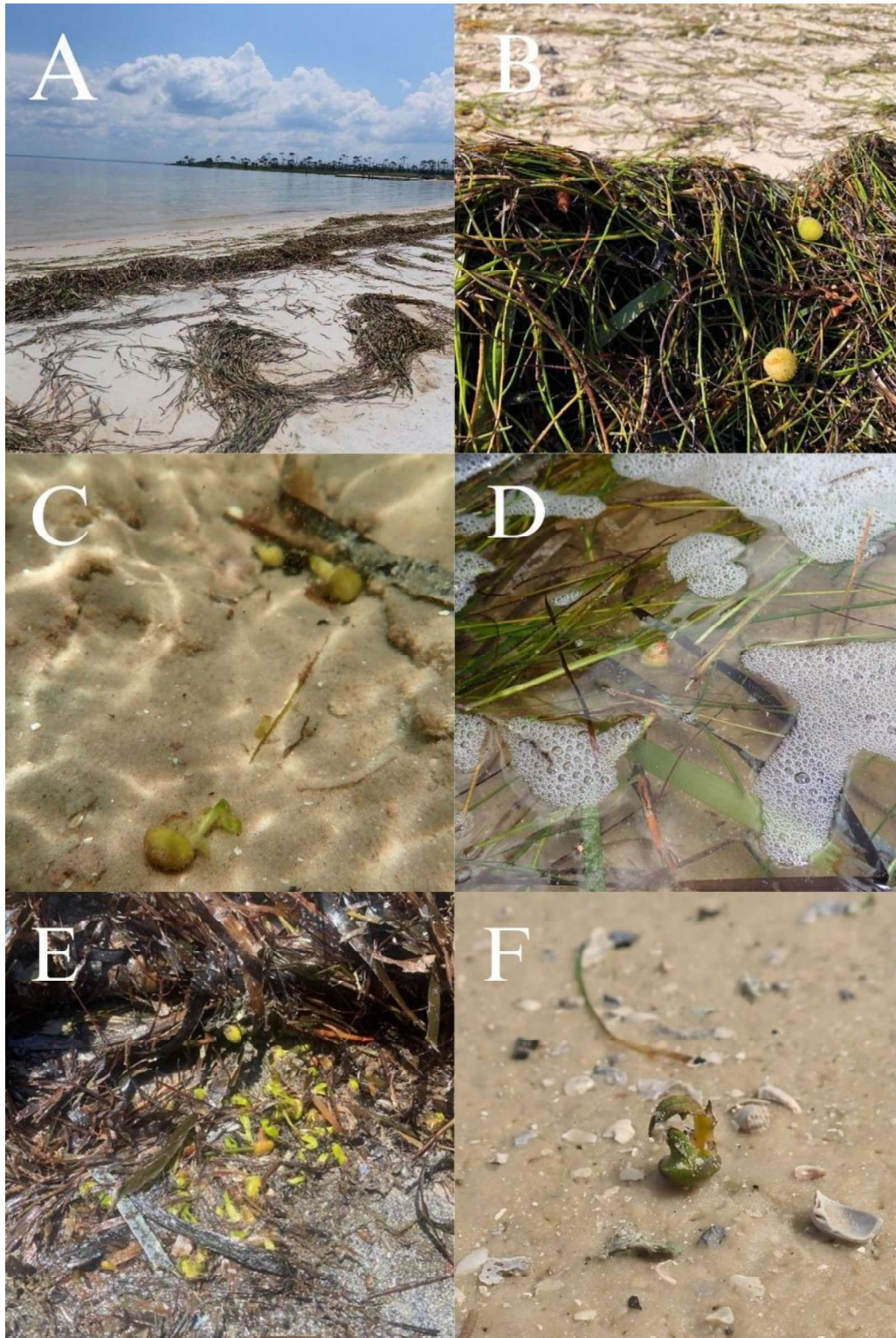


Figure 3: A) T. testudinum wrack on the beach at St. Joseph Peninsula State Park. B) Two T. testudinum fruits beached on a pile of seagrass wrack. C) Three seedlings submerged, (one in the foreground, two in the background) lying on the seafloor. D) Positively buoyant seedling with seed coating floating among seagrass wrack. E) Several seedlings with blades found underneath old seagrass wrack. F) Desiccated seedling with a blade found on the shore.

It is important to identify seedlings in their various stages of development to recognize them in the field (Figure 4). Freshly released seedlings have a white or tan buoyant coating and will appear slightly different from seedlings in later developmental stages. These young seedlings will be approximately 10-15 mm in diameter and can either be found floating in the water or up near the high tide line. Seedlings that have lost their buoyant coating will be negatively buoyant and appear bright green or brown. Submerged seedlings will typically be caught in small divots in the sand or trapped beneath submerged wrack near the shoreline. Seedlings found on shore will be anywhere between the water's edge and high tide line. Every beach is different, and their unique features will determine where seedlings will accumulate. Incoming to early outgoing tides were found to be favorable for seedling collection.



Figure 4: Left: *Thalassia* seedling with initial blades, seed coat, base, and fine root hairs. Right: *Thalassia* seedling development: A) freshly released seedling with buoyant seed coat. B) Seedling with seed coat turning brown, no first blade yet. C) First blade is emerging. D) First blade is erect. E) Seedling with multiple blades.

With each tidal cycle, seedlings on the high tide line will burn from hours of direct sun exposure. This results in varying degrees of desiccation and light damage that can result in browning (Figure 5). Severe heat stress drastically reduces the likelihood of survival. The six seedlings in Figure 5 (right) would most likely be nonviable and could be left onshore. Seedlings that are not desiccated and mostly green have a greater chance of survival in the nursery.



Figure 5: A) *T. testudinum* seedlings with mild browning on the tips of blades and seed base due to heat stress. May still be viable. B) *T. testudinum* seedlings with severe browning due to heat stress. Likely nonviable.

T. testudinum fruits can also be collected alongside seedlings. Each fruit can contain up to six seedlings, although two to three is most common (Figure 6). It is important to store fruits in a separate container or bucket with seawater. Once fruits dehisce, the exocarp, or outer layer, quickly disintegrates and causes excessive bacteria build up which can harm the seedlings. It is best to monitor the fruits daily to remove exocarps as they dehisce and refresh the water in the container. Freshly dehisced seedlings can be floated in a bucket of clean saltwater until they sink to the bottom.

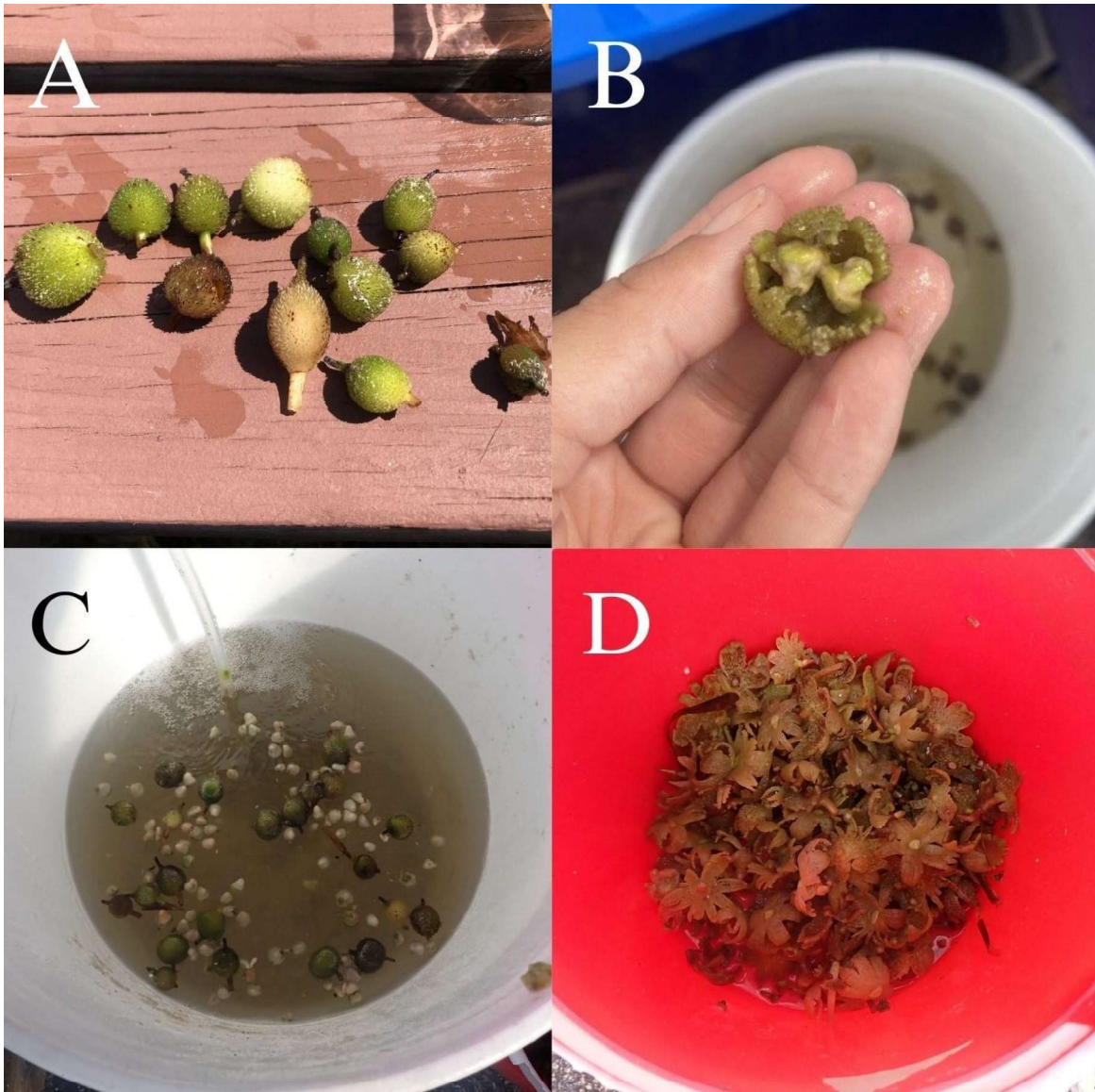


Figure 6: A) Unopened *T. testudinum* fruits. B) A dehisced fruit with two seedlings inside. C) Fruits stored in a separate bucket with bubbler, surrounded by freshly dehisced, positively buoyant seedlings. D) Discarded exocarps of dehisced fruits.

Once the seedlings are collected, they can be transported in plastic zipper bags with enough seawater to completely submerge them. DO NOT store seedlings in freshwater! If you are visiting multiple sites in a day, keep in mind the internal temperature of the car sitting in the sun. To maintain temperatures of 20-30°C, store plastic zipper bags in a cooler with ice or ice packs. If seedlings need to be stored in bags for more than 24 hours be sure to change the seawater daily. If fruits dehisce in the bags during storage, remove excess fruit material and replace the water. Seedlings can be stored using this method for up to a week but be sure to expose seedlings to indirect sunlight periodically to allow for photosynthesis.

Nursery Setup

Seagrass nurseries control environmental conditions to provide a stable environment for seedling growth. The nursery or greenhouse can be completely customizable; however, there are a few absolute necessities for a successful setup: tanks, water source, filtration, lighting and temperature regulation. Each nursery will be unique due to the challenges of location and available resources, but the following approach yielded two years of seedling growth and may serve as a template for your project.

Water

When filling tanks for the nursery, water can be obtained several ways. Local seawater can be collected and stored in drums for use as needed. If collecting local seawater, be sure to check water quality conditions for the collection area. Do not collect seawater during algae blooms or other poor water quality events. Another option is creating saltwater using aquarium salt. Using commercial aquarium salt brands, such as Instant Ocean™, are a viable alternative to natural seawater.

Salinities should be constantly monitored to reduce seedling stress. Seedlings will be collected from a variety of different salinities, so slowly acclimate seedlings to a common salinity. While *T. testudinum* seedlings can tolerate a range of salinities from 20 to 40 (Kahn & Durako 2006), seedlings suffer greater stress in high (50+) salinity environments (Howarth & Durako 2013). Choose a salinity similar to the potential outplanting site to promote growth under outplanting conditions. Salinity can be adjusted by the addition of fresh water or salt to the preferred value.

Conduct water changes as needed to maintain good water quality. An excess of nutrients in tank water may cause algae blooms and stimulate epiphyte growth, which may reduce seedling growth (Tomasko & Lapointe 1991). While excess macroalgae can be removed manually, reducing nutrient concentrations through routine water changes is the primary method of controlling algal growth. If a tank consistently experiences algal blooms, consider reducing light duration until the bloom is controlled.

Filtration

Filtration systems will be determined by the tank setup of the nursery. Filtration is still necessary to create water movement and reduce the formation of anoxic areas within the tanks. *T. testudinum* seedlings do not require the same amount of filtration as marine fauna and will cycle nutrients and produce oxygen which will improve tank water quality. High water flow may uproot young seedlings, so choose a low to moderate flow that adequately moves water without uprooting the plants. Flow rate can be adjusted manually on the filter, by air valves, or by baffling the flow output.

There are many different options for tank filtration, and each have their own benefits. Under-gravel filtration can be customized to a variety of tank sizes, is relatively inexpensive, and requires little to no maintenance (Figure 7). This system uses an air pump connected to air stones to gently move water down through shell or gravel and out through raised tubes. Internal canister filters can be used to move tens to hundreds of gallons per hour and are effective at removing detritus and debris from the water column. External canister filters are best used in large, interconnected tank systems with high water volumes.



Figure 7: Small scale version of a PVC under-gravel filtration system in a 20-gallon aquarium.

Lighting

If the seedling greenhouse is located outside, no additional lighting is required. Plants should have access to 50-100% full sunlight whenever possible. However, lower light levels can impact plant growth and morphology (Genazzio & Durako 2015). The use of grow lights can create a consistent light source for the young plants regardless of environmental conditions.

For indoor tanks or greenhouses with supplemental lighting, LED full spectrum grow lights or aquarium lights are excellent light sources. 80-watt grow lights producing 4,000 lumens have proven effective at growing seagrasses. Ensure the grow light is properly protected from water and salt intrusion. Lights should be placed 1-2 feet above the water surface. Use a timer to set lights for a 12:12 to 8:16 light:dark cycle. Lighting duration can be adjusted as needed to deter algae blooms.

Temperature regulation

Water temperature in the tanks should be closely monitored to reduce seedling stress and promote growth. *T. testudinum* seedlings should be kept in a temperature range of 20-30°C (Phillips 1960). While seedlings can be exposed to extreme temperatures for short periods, prolonged exposure may cause mortality (McMillan 1979).

The use of shade cloth can reduce the sun exposure and lower water temperatures. Fans can be used to increase air flow within the nursery/greenhouse. For larger nursery setups, a chiller may be necessary to maintain optimal temperature. Providing shade over external filters and sumps can also prevent water from heating during filtration.

In the winter, water can be warmed using aquarium or pond heaters. *T. testudinum* generally exhibits reduced photosynthesis during winter periods (Czerny 1994); however, by manipulating water temperature you can increase seedling growth rates. Water temperatures should be maintained at summer growing conditions (30°C) to maximize productivity during the grow-out period (Zieman 1975). The addition of clear plastic covers can be used to reduce evaporative cooling and to retain water and heat within tanks.

Planting Techniques

Planting Units

Once you have collected your seedlings, it is time to stock the nursery. Planting units can be created with a variety of different materials including plastic pots, trays, buckets, Tupperware™, etc. (Figure 8). It is important to consider how you will fill space and how you will interact with the planted material during the grow-out period. We used plastic plant pots and plastic trays of varying sizes and did not find that size affected seedling survival, so select the size that fits best within your nursery setup and provides the ease of transport needed for eventual outplanting. It is also important to consider the outplanting location when selecting a planting unit container. Our experiments displayed that trays are more effective for high energy outplanting sites, while pots were more effective and easier to use in low energy locations.



Figure 8: Different types of containers being used to cultivate T. testudinum seedlings.

When planting in pots, choose sturdy, injection molded pots to reduce the potential for cracking and breaking. We recommend square pots to maximize the total available area within greenhouse tanks. The snug fit of square pots reduces gaps between pots, minimizing the available area for algal growth (Figure 9). Biodegradable and organic pots are not recommended due to the extended holding time of the seedlings during grow-out, as well as the corrosive nature of salt water. Small (2-in²) pots are useful for planting individual seedlings; however, they require much more work to move and transport during outplanting. In addition, small pots hold a limited number of seedlings. Medium sized pots (4-in²) provide adequate planting area for multiple seedlings per planting unit while still being small enough to handle. Large pots (5.5-in²) may become strained and crack under the pressure and weight of wet sediment. They are more difficult to move within the tanks and can fit fewer planting units per tank. Large pots also waste space by having excessive sediment space; it is unlikely that the entire sediment space available will be used during the grow-out period. We recommend the use of medium sized pots for creating planting units for low energy outplanting locations.

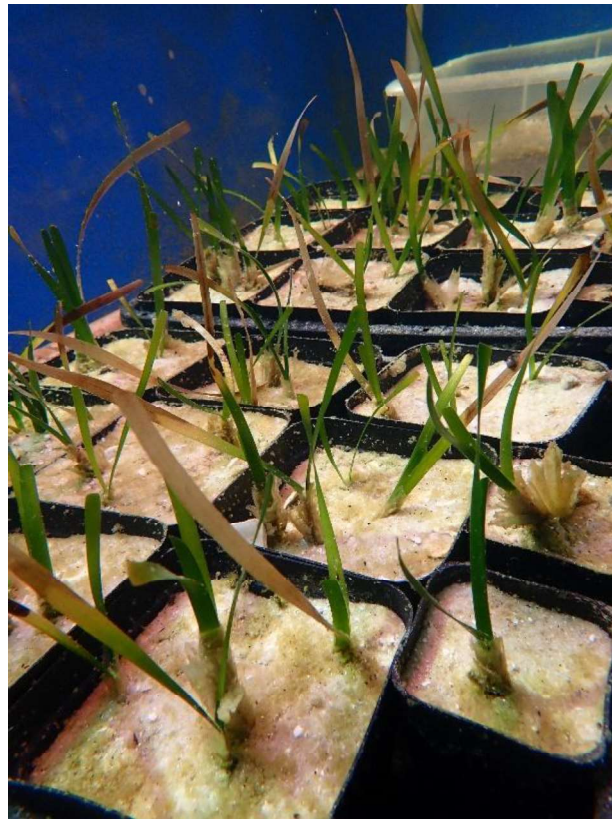


Figure 9: Planting units in square, injection molded plastic pots.

Shallow plastic storage trays are another potential container for planting *T. testudinum* seedlings (Figure 10). Trays can hold more seedlings than pots due to their larger overall area and can be an effective planting unit for high energy outplanting locations. Previous experiments have shown that roots from one individual can span the entire distance of the tray, intertwining with other plant roots along the way. This can result in a tightly bound seagrass mat. When choosing trays, select shallow over deep trays. While deeper trays can contain more sediment, this area is rarely used by roots during the short grow-out period and creates a large, anoxic layer. During our experiments, tray sizes varied from 8-in² to 2-ft². When selecting a tray size, keep in mind the weight of the sediment within the tray. Larger trays may be able to fit more seedlings; however, they are very difficult to transport due to weight and size. The preferred tray size in our experiments was 9x15x3-in.

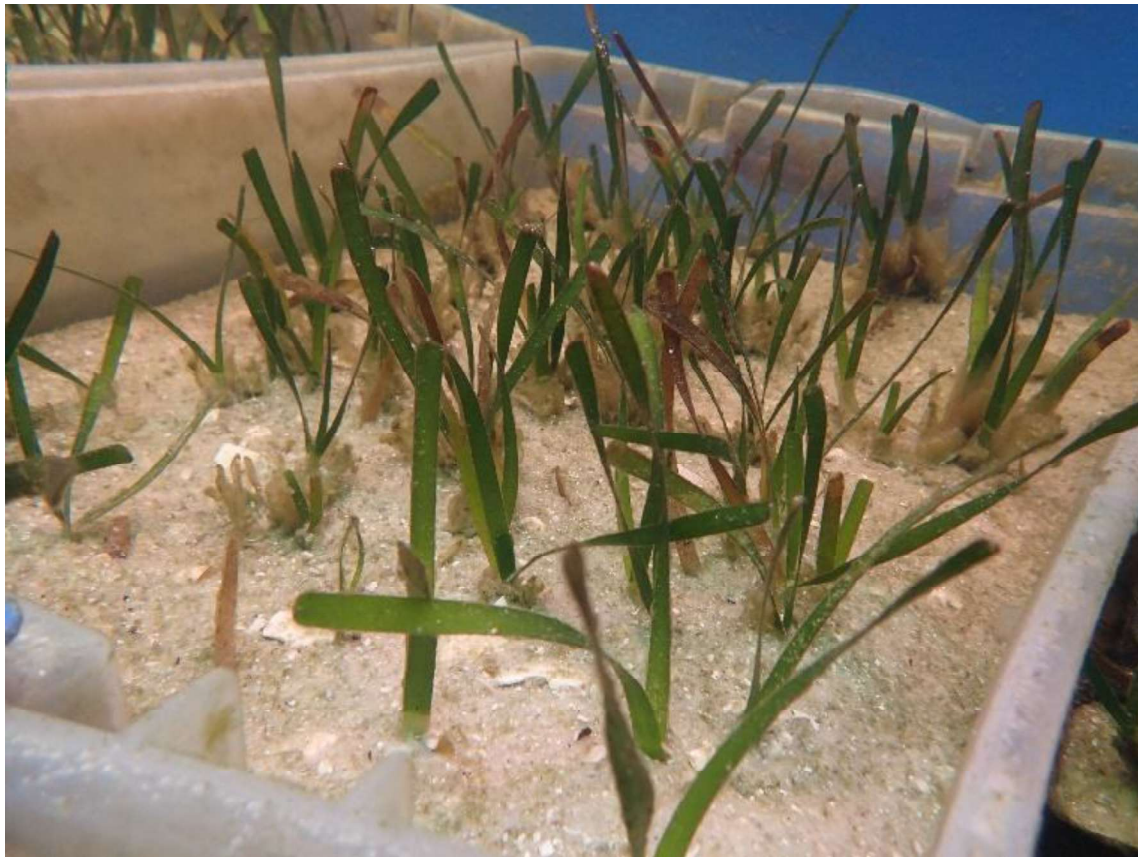


Figure 10: Planting unit in a plastic tray, 9x15x3-in.

Sediment

During our experiments seedlings were planted in beach sand (grain size 0.25-0.55-mm), collected locally and rinsed with fresh water to remove organic debris. The sediment was dried and had large shell fragments removed before use in planting. Planting can occur in a variety of different grain sizes; however, we suggest using sediment similar to the recipient site. The initial root hairs need to attach to sediments to increase the stability of the seedling in the pot or tray (Figure 11).



Figure 11: Grains of sediment beginning to attach to the initial root hairs of young Thalassia seedlings.

When filling the planting units, we followed a specific sediment layering scheme (Figure 12). Fill the bottom of the container with a thin layer of shell hash. This will ensure the container is bottom heavy, as well as fill any potential holes in the container and prevent sand from escaping out the bottom. It will also provide larger shell fragments for future seagrass roots to attach to, increasing the total mass of belowground material when planting. Providing material for seagrass roots to adhere to will increase planting unit stability.

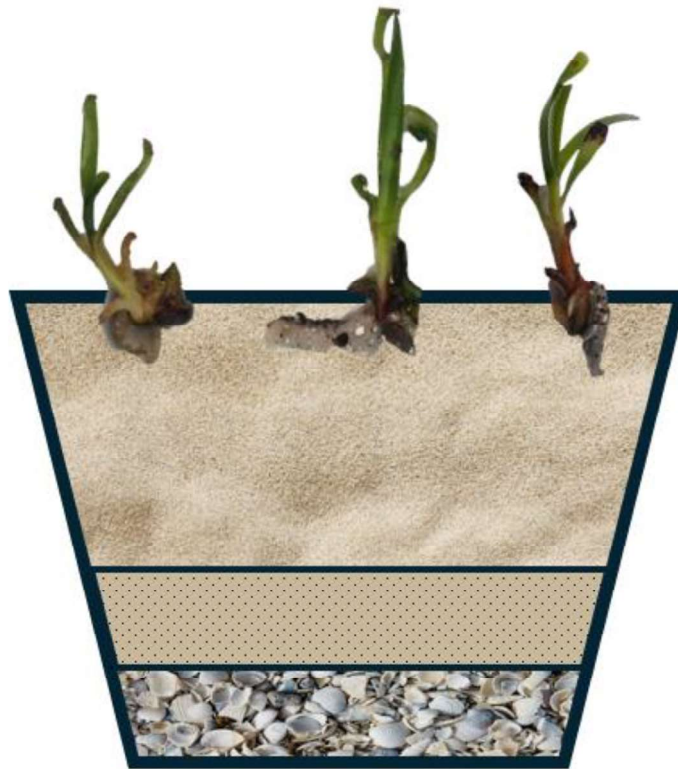


Figure 12: Proposed sediment layers for planting units. Bottom layer of crushed shell, small middle layer of 30% peat-sand mixture, top layer thick sand cap.

Following the shell hash layer is a thin sand and peat mix layer. Peat is rich in nitrogen, phosphorus and iron, nutrients that can positively impact the growth of *T. testudinum* (Lee & Dunton 1999). Compressed peat is hydrated with salt water and dried, then mixed with cleaned beach sand. The mixture should be about 1:3 peat to sand. This provides a small layer of nutrient rich organic material for root growth. Other fertilizers such as Osmocote™ can be used in lieu of peat in controlled doses. It is important to maintain the 1:3 ratio (peat:sand) as excess organic matter may fuel sulfide reducing bacteria that are detrimental to root growth.

The largest and final layer should be clean beach sand, which can be purchased from building supply stores. The sand will provide a thick cap over the nutrient layer, keeping the organic layer firmly in place and preventing the nutrients from leeching out of the planting unit. It is within this layer that the initial root hairs and roots will begin to establish. Large shells or rocks should be removed before planting to allow roots and rhizomes to grow unobstructed.

Planting units should be constructed out of the water. This prevents the tank water from becoming overly turbid, as well as stops the peat from the middle layer from floating away before being capped with sand. Once the planting unit is sunk and air bubbles have dissipated, add extra clean beach sand to the top of the unit as needed. Filling the planting units to the brim reduces the area in which algae and bacteria can grow on the pot surface and prevents water stagnation.

Planting Seedlings

Once the planting units have been filled, it is time to determine the number of seedlings in each unit. Planting multiple seedlings per unit reduces total outplanting effort, creates intertwined root systems to stabilize planting units, and increases the chances of success both in the nursery and at the recipient site.

While storing seedlings prior to planting, pay special attention to the bacterial growth. This may appear as a white or pink color on the base of the seedling. This bacterial growth, if left unchecked, may kill the seedling. Ensure the seedling storage has adequate flow and remove dead seedlings daily to reduce bacterial growth.

Determine the average range of *T. testudinum* shoots per m² for the intended outplanting area (Figure 13). Using this number, calculate the number of seedlings needed to reach the lower density average using the area of the planting unit. Our studies have indicated planting at lower densities increases the seedling survival rate without impacting root or rhizome development. For example, *T. testudinum* shoot densities range from 200-600 shoots m⁻² in various parts of Tampa Bay (Tomasko & Dawes 1990, Dawes 1998). Planting a 4-in² pot at a density of 300 shoots m⁻² would equal planting three seedlings per pot, while planting a 9x15-in tray at this density would equal planting 26 seedlings. The density of the planting unit can be adjusted to best suit the target outplanting density. However, our experiments showed that increasing the seedling density within each planting unit does not increase seedling survivability. Increased seedling density can result in seedling competition for resources.



Figure 13: Pot (4-in²) planting units with varying seedling densities.

T. testudinum seedlings can be exposed to air for short periods of time; however, do not let them fully desiccate. *T. testudinum* seedlings are viviparous, germinating prior to fruit dehiscence and thus cannot be dried and stored as many terrestrial seeds can. When working with seedlings, keep them hydrated in salt water and do not expose them to air for longer than a few minutes at a time.

When choosing seedlings to plant, be conscious of their condition. Viable seedlings will be mostly green, although seedlings with some brown/senescent blades may recover over time. Dead seedlings often appear completely brown and lose their initial blades when applying slight pressure. In a healthy seedling, the seed base should be mostly green and firm when applying slight pressure. Non-viable seedlings may have a ‘squishy’ base which extrudes rotten material when pressed. Dead and rotten seedlings should be removed from the healthy seedling population as soon as possible. Floating seedlings after the removal of the buoyancy seed coat may be a sign of decay.

Before placing seedlings into the sediment, the age of the seedling should be considered; the same technique will not work for freshly dehisced seedlings as it might for older seedlings with blades and roots. If the seedling is very young (i.e., freshly removed from the fruit), it should not

be planted until its first blade is erect and growing. The epidermis of the seedling is photosynthetic (Celdran 2017), therefore burying the entire seedling will deprive the young plant of some of its photosynthate. Place these seedlings in a nursery tank in a storage container with sand and wait a few days for the initial growth spurt. Seedlings will slowly right themselves blade up, seed reserve down, and root hairs will develop to hold the seedling in place (Figure 14). When the initial blades on the seedling are approximately 1 cm or longer, gently bury half the seedling base in the sediment. If root hairs have already developed, plant the seedling deep enough that the root hairs are covered by sediment. The goal is to use enough sediment to hold the seedling in place while it develops a more robust root system.

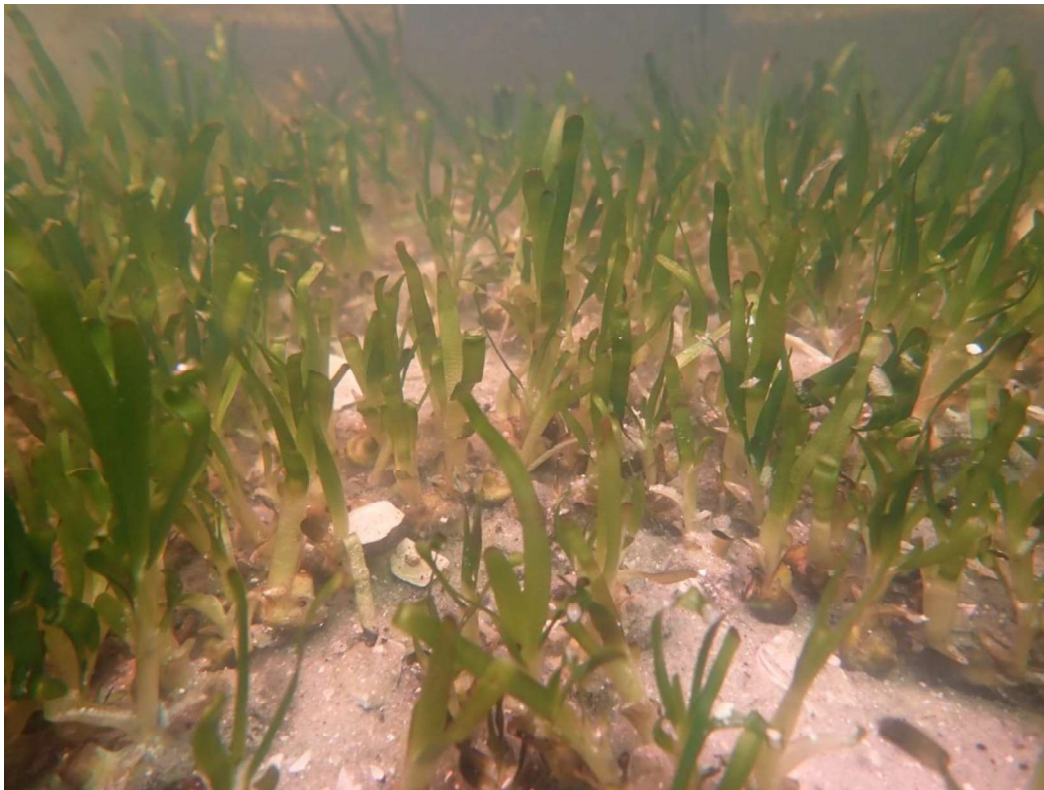


Figure 14: Two weeks after collection and prior to planting, seedlings had all positioned themselves blade up, seed reserve down.

Research is underway to determine the ideal grow-out time to hold seedlings before outplanting. Young *T. testudinum* roots can grow rapidly within the initial months following release, however the young plants are still vulnerable to many different environmental factors. It is suggested that seedlings should be held for approximately 8 months prior to transferring them

to the field. If seedlings are collected in late July to early August, outplanting may occur as early as April the following year.

Outplanting

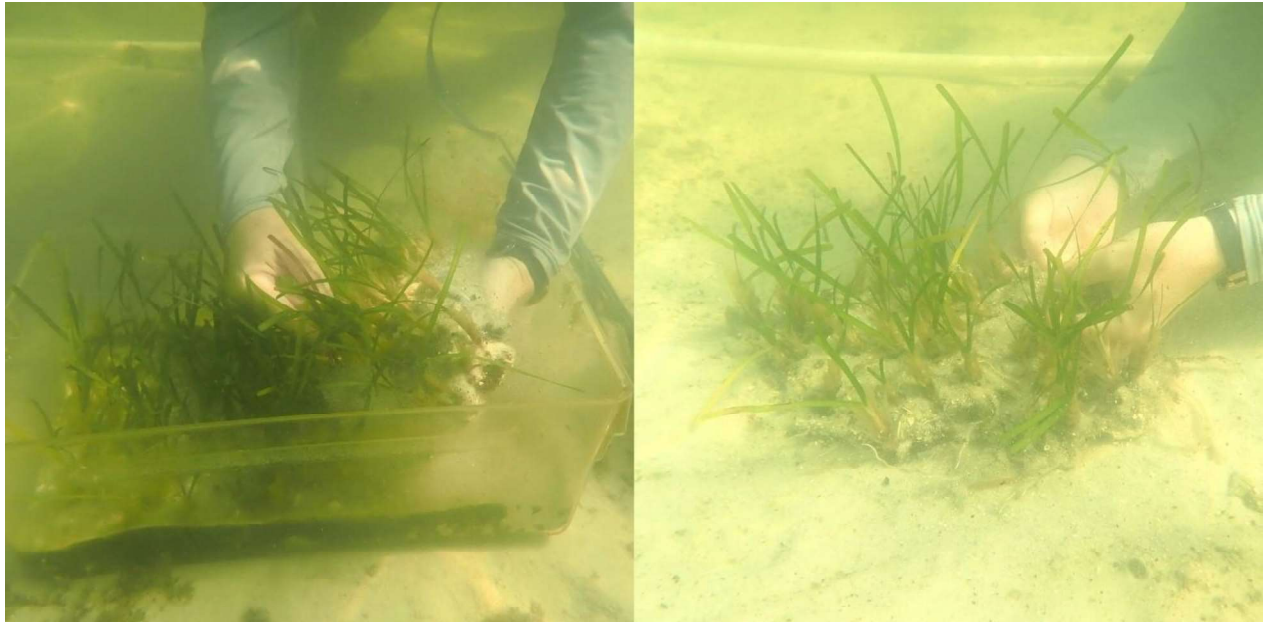
When the young *T. testudinum* plants are ready to be outplanted, the entire planting unit will need to be transported to the restoration site. The planting units described above require the entire unit, sediment and all, be moved to the restoration site and planted. The units can be placed in large coolers or heavy-duty totes and covered with salt water to approximately an inch above the sediment. Cover the water surface with a thin cloth or bubble wrap to prevent excess sloshing during transport. Avoid storing the planting units in direct sunlight during transport to prevent overheating.



Figure 15: Example of potted planting unit installation.

Using pots for planting units provides a quick and easy planting experience. When outplanting, invert the pot with a hand over the plants and gently jiggle the roots and sediment out of the pot. Using a trowel, dig a small hole in the desired planting location. Place the planting unit

upright within the hole, then carefully cover roots with sediment (Figure 15). Finally, place a metal yard staple over the planting unit to hold the roots into the sediment. We recommend using yard staples approximately 4 inches in length to secure planting units into the sediment.



*Figure 16: Interwoven mat of *T. testudinum* seedlings removed from tray, preparing to be planted.*

In tray planting units, the *T. testudinum* roots will likely create a dense, interwoven mat that will maintain the shape of the tray (Figure 16). Scrape away sediment in the preferred planting area, place the seagrass mat down and return the displaced sediment. Tray planting units require yard/sod staples to hold it in place. Stake 3-4 metal staples at various points throughout the unit. This planting method works well for planting in disturbed areas, such as scars or higher energy locations. It also helps protect the seedlings from invertebrate bioturbation by anchoring the plants with a strong matrix of roots.

Conclusion

The methods described in this report have been applied to an ongoing pilot restoration project in Tampa Bay. Approximately 1,900 nursery-grown *T. testudinum* seedlings have been outplanted across 16-m² from 2023-2024. Seedling survival is being monitored monthly and preliminary data suggests these methods can be scaled to restore larger areas. Studies on seedling planting densities and genetic biodiversity of shore cast seedlings are currently underway to further improve seedling-based restoration techniques.

The application of *T. testudinum* seedling-based restoration can be scaled as needed to fit the desired restoration project. A productive collection site may yield thousands of seedlings within a few hours and can be revisited multiple times until the material runs out. However, initial seedling costs may be high depending on the target restoration area. One acre of *T. testudinum* restoration using seedling-based methods can require over 800,000 seedlings to reach a density of 200-shoots/m². Although the initial material costs may seem intimidating, the result is a young, genetically diverse seagrass bed composed of a climax species. As the grassbed matures and develops, clonal growth will increase shoot density and maintain the grassbed. After two years the planted *T. testudinum* will reach sexual maturity and begin to produce seedlings, allowing for further expansion of the species within the region.

T. testudinum seedlings can also be used in conjunction with *H. wrightii* based restoration approaches. *H. wrightii* is a fast-growing pioneer species often used in Florida seagrass restoration (Rezek et al. 2019). Several studies have investigated co-planting *T. testudinum* and *H. wrightii* with positive results (Derrenbacker & Lewis 1982, Durako & Moffler 1987). Using the rapid growth of *H. wrightii* to stabilize sediments and accumulate nitrogen may be beneficial to the establishment of *T. testudinum* seedlings (Williams 1990). Future research efforts should study the use of *T. testudinum* seedlings as supplemental planting during *H. wrightii* restoration, as well as plantings several years after restoration efforts. The use of *T. testudinum* seedlings in combination with *H. wrightii* based restoration could increase habitat complexity within newly restored seagrass beds and accelerate the transition process from pioneer to climax seagrass community.

The application of *T. testudinum* seedling-based techniques has incredible potential for seagrass restoration. Shore-cast seedlings provide genetically diverse salvage material for seagrass restoration without harming extant seagrass beds. It is important to emphasize that these efforts should not be used as a replacement to ongoing or future nutrient reduction efforts. Seedling planting can be used in combination with nutrient reduction efforts to help jumpstart seagrass recovery in locations where vegetative and reproductive material from nearby established meadows is unavailable. Further research will explore the viability of this technique and increase the restoration potential for this slow growing climax species. We hope this report will provide a starting point for parties interested in seagrass restoration using shore-cast *T. testudinum* seedlings.

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