SEAGRASS RESTORATION HANDBOOK:

THE HOW, WHEN, AND WHERE OF RESTORING SEAGRASS HABITAT THROUGH TRANSPLANTATION

Lessons from Elkhorn Slough

Funded by The Anthropocene Institute

Special thanks to the following for the creation of this Handbook:

Brent B. Hughes, Sonoma State University; Kathryn M. Beheshti, University of California, Santa Barbara; Katharyn E. Boyer, Estuary & Ocean Science Center, San Francisco State University; Susan Williams, University of California, Davis

Editors: Barbara Page and Ford Brodeur, The Anthropocene Institute

In Memory of Susan Williams

Instructional Video

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Photo Credits

All photos in this handbook are credited to Dr. Brent Hughes, Dr. Kathryn Beheshti, and Dr. Melissa Ward, from their "How to" of Seagrass Restoration, Seagrass Transplant and Restoration Team (START) video series (2021), unless otherwise noted.

All monetary values are expressed in U.S. Dollars (USD) as of 2024.

Introduction & Background

This handbook was created to offer valuable insights and guidance from a successful seagrass (*Zostera marina* – commonly known as eelgrass) restoration project (2015-2018) in Elkhorn Slough, located within Monterey Bay, California, USA focusing on restoration through transplantation. The information, materials, and expertise found in this handbook are meant to help guide you step-by-step in conducting a seagrass restoration of your own if transplantation is appropriate, including tips to help you scope transplantation projects.

It is important to note that most seagrass restorations do not succeed, in fact, they often fail. Researchers highlight that the majority (63%) of seagrass restoration attempts are not successful (van Katwijk et al., 2016). However, our project was different. Our project had ~40% of its plots remaining after two years post-transplantation, and the restoration area reached up to **85 times the original plot size.**

The restoration began in 2015, and we planted 1,020 shoots in 51 plots, each measuring 0.25m^2. In 2016, the number increased to 1,320 shoots in 66 plots of the same size, totaling 2,340 planted shoots. When we planted these plots, some were planted near the existing seagrass beds of Elkhorn Slough, ensuring they stayed less than a hundred meters from any existing seagrass bed. However, we also aimed to plant spots farther up the estuary and in areas where seagrass had never previously existed but still met conditions for seagrass survival. We avoided planting in Elkhorn Slough in areas that did not meet the right conditions for seagrass growth, such as areas with scouring, which is when strong water movement moves or clears sediment and can expose and harm the roots of seagrass plants or when light meters indicated that lighting was inadequate.

Within 3 years (2015-2018), the restored 0.25m^2 plots expanded ~8,500% from a total initial area of 29m^2 to 2,513 m^2. The plantings showed consistent success across our restoration area, covering from the Highway 1 bridge to approximately halfway up the Elkhorn Slough estuary.

The success of this project is particularly notable since the global success rate of seagrass restoration is approximately ~37%.

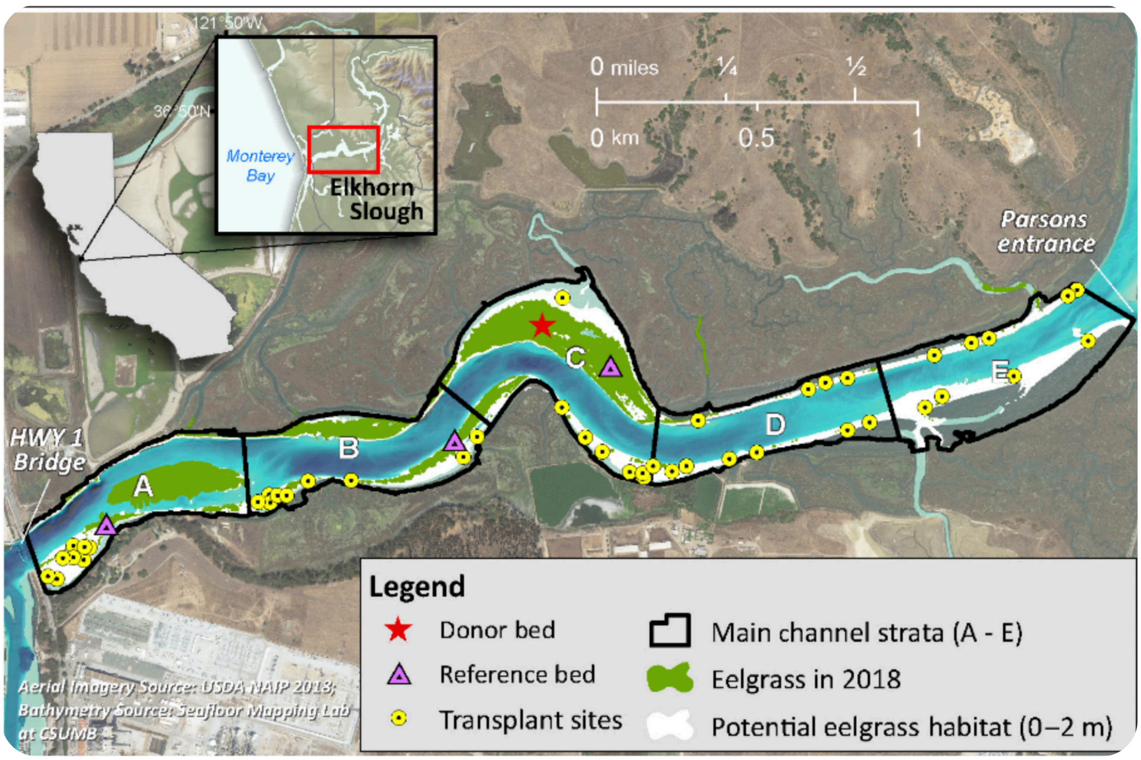


Image 1: The map above shows the Elkhorn Slough Restoration sites. (Source: Beheshti et al., 2022)

The success of this project was also notable because Elkhorn Slough estuary has one of the highest rates of nutrient-pollution in the world, which we believed reduced our chances for successful restoration. When we launched our restoration project at this location, we wanted to see whether restoration ***could*** succeed, which led us to take an experimental approach to this restoration.

At the conclusion of our 3-year restoration project in 2018, our experimental project achieved remarkable success. The seagrass exceeded our initial expectations, growing beyond what we thought a restoration project could achieve at Elkhorn Slough.

Moreover, this success resulted in:

- Overall greater ecosystem productivity
- Increased invertebrate diversity
- Greater carbon burial
- A less acidic environment
- Improved dissolved oxygen levels near the restored seagrass
- Reduced water temperatures due to the seagrass canopy
- Increased crab populations (compared to non-restored areas)

While not every project requires the same experimental approach as ours, we wanted to share the information and techniques we used that brought us success at Elkhorn Slough. By sharing this information and techniques within this handbook, our goal is to help you to achieve similar success in your project.

Much of the information in this manual draws upon decades of seagrass restoration throughout California and beyond, and much of it comes from our restoration experiences in Elkhorn Slough (see Beheshti et al. 2022) and San Francisco Bay. This manual expands on a previous version of the manual by the same group of co-authors (Beheshti et al. 2018).

Image 2: Dr. Brent Hughes working in Elkhorn Slough, California. Image taken from Hughes, Beheshti, Ward. 2021. “How to” of seagrass restoration. Seagrass Transplant and Restoration Team (START).

The Importance of Seagrass

Seagrasses are marine angiosperms, consisting of 3 families (Zosteraceae, Cymodoceaceae, and Posidoniaceae) usually found in shallow coastal waters from tropical to temperate climates. In general, seagrasses form narrow grass-like leaves that can form dense underwater meadows (Hartog and Kuo, 2010). The restoration of seagrass meadows is important because seagrasses offer many ecological benefits. These benefits include the regulation of dissolved oxygen and filtration of contaminant runoff from land (Reynolds, 2023; Ricart et al., 2021).

Seagrass also creates habitat (Maxwell et al., 2017; Van Der Heide et al., 2007) for fish, birds, marine mammals, and invertebrate animals such as clams, shrimp, and crabs. Large megafauna, such as sea turtles and manatees, also rely on seagrass for sustenance. Seagrass creates a 3-dimensional structure that slows down water flow, facilitating the settlement of suspended material, improving water clarity. Its roots anchor in the sediment, slow down coastal erosion, and protect the shoreline from storm damage. Additionally, seagrass structure traps carbon by storing it into the sediment, which helps combat climate change (Beheshti et al., 2022; Reynolds, 2023). In its ability to store carbon, researchers estimate that seagrass sequesters carbon 40 times faster than terrestrial areas (Mcleod et al., 2011). Additionally, native seagrass species play an important role in fighting climate change. In a study comparing native versus non-native seagrass in the U.S. Virgin Islands, native seagrass sequestered 1.3 times more carbon than non-native beds (Brenner et al., 2023).

In addition to positive ecological and climate benefits, seagrasses also provide indirect economic benefits. For instance, in 1997, researchers estimated that seagrasses offer an economic value of around $22,832 USD per hectare per year within the ecosystem (Costanza et al., 1997). They provide essential habitats for juvenile aquatic creatures, such as the Dungeness crab, which brings in an annual economic value of $100 million USD along the U.S. west coast (Hughes, 2014; Grimes et al., 2020). Also along the shoreline, seagrasses slow water movement and trap sediments, providing defense against wave-induced coastal erosion. Healthy seagrass meadows in coastal areas can help to save money and resources by reducing repairs to businesses and properties, directly extending economic benefits.

The Global Decline of Seagrass

Unfortunately, seagrass ecosystems are among the most threatened on our planet (Waycott et al. 2009, van Katwijk et al., 2015). Since the early 1900s, there has been a global decline of the known and surveyed seagrass meadows. 5602km^2 of seagrass were lost (Dunic et al., 2021). Since 1900, only approximately 554km^2 of the known and surveyed seagrass meadows were able to recover (Dunic et al., 2021). The largest causes of historical seagrass loss found in this and other research were human-caused: coastal development and poor water quality (nutrients, algal blooms, and sediment; Dunic et al., 2021; Burkholder et al. 2007).

Human actions contribute to seagrass habitat decline, but human actions can also play a role in protecting seagrass and in restoration. To protect seagrass, people should support local conservation efforts, limit pesticide and fertilizer use, and boat slowly and anchor carefully in areas with seagrass (Reynolds, 2023). Seagrass restoration can take place while protective laws are being established, and everyone can play a role in their restoration.

The Road to Restoration

It is important to make a continual effort to restore these ecosystems. Despite challenges in popularity (compared to terrestrial restoration) and bottlenecks in knowledge sharing by practitioners (Ward and Beheshti, 2023), actively promoting seagrass restoration is essential to revitalize these important habitats and counteract coastal erosion.

This handbook aims to share knowledge and facilitate seagrass restoration with the tools, know-how, and guidance to start planting seagrass on your own. We hope you can leverage the lessons learned and knowledge gained through our restoration work in Elkhorn Slough and beyond to help make your restoration project a success.

Why We Chose Elkhorn Slough

Site selection is critical for the success of seagrass restoration. Poor conditions reduce seagrass survival, leading to its decline, so choosing a promising restoration site is a crucial first step for the success of your project.

For the site of our successful restoration, we choose Elkhorn Slough, an estuary located in Monterey Bay, California, USA based on six-key factors:

01	Proximity and familiarity to the site
02	Presenting a new approach
03	Historical knowledge of Elkhorn Slough natural history and seagrass ecology
04	A healthy food web[1]
05	Limited motorized boat activity
06	Restoration in marine managed areas and marine facility access

Below we will expand on why these factors played such an important role in our site selection:

1. Proximity, Familiarity to the Site

Our team that took part in this project all resided in northern California at the time of restoration. Elkhorn Slough was a short driving distance away, and this was an influential factor in selecting this spot because it was logistically easier to restore and monitor.

Initially, we did not expect success since previous seagrass restoration efforts in Elkhorn Slough, starting in the 1980s, had failed. It is known that large amounts of agricultural runoff flows into the estuary (Hughes et al., 2011; Hughes et al., 2013; Wasson et al., 2017). However, conditions changed. Seagrass in Elkhorn Slough was experiencing a rare reversal of decline. We were inspired and wanted to see if that recovery could be accelerated. However, the idea we had was experimental because Elkhorn Slough is categorized as one of the most nutrient-polluted estuaries globally.

1 https://www.nationalgeographic.com/animals/article/sea-otters-make-seagrass-meadows-resilient

2. Presenting a New Approach

Our team tested Elkhorn Slough's suitability to determine if the project could work. We utilized existing water quality data (light and turbidity, and on-site considerations regarding the quality of the sediment, which are described in detail in the section on Assessing Location Suitability on page 21 (also see Hughes et al. 2011)). After these measurements, we felt confident an experimental restoration effort would be worthwhile. To understand the ideal conditions for seagrass survival, please refer to Assessing Location Suitability on page 21. Then, to test our ideas, we divided the estuary into five sections (or blocks) and randomly planted.

We randomly planted seagrass in areas that had:

- The right conditions for seagrass survival[2]
- A pre-chosen tidal elevation range (from -2 to -1 meters MLLW, Mean Lower Low Water) that could serve as potential seagrass habitat. This elevation range below the average lower low tide water mark indicates where seagrass might potentially survive based on previous observations. Seagrass in higher elevations tends to dry out (desiccation).
- An appropriate distance from existing seagrass beds throughout the estuary (at least 25 meters from naturally occurring seagrass beds)

We note that our restoration design was highly experimental in approach. Typical restoration designs will have restored plots in more concentrated areas. For example, a typical example restoration design would focus on a smaller, singular area for the restoration (e.g. 1 hectare). Our experimental design differed from typical restorations since we chose multiple areas across Elkhorn Slough to plant in (see image below) as well as our restoration being located in a globally recognized nutrient polluted estuary. This experimental restoration design gave us the chance to see which parts of Elkhorn Slough would support seagrass restoration best. We suggest using the approach of planting in high densities in clumps throughout a restoration area, as planting in clumps has been shown to enhance restoration success in marine vegetation (Silliman et al., 2015). Planting at higher densities more closely mirrors what we observe in natural meadows and may allow for quicker recovery of desired ecosystem functions or services.

Left: A typical seagrass restoration that occurred in Madagascar (UNEP-Nairobi Convention/WIOMSA, 2020). Right: A snapshot of the larger experimental Elkhorn Slough restoration plan that was undertaken across five sections of the Elkhorn Slough estuary. This image was taken from a drone video by Katharyn E. Boyer, San Francisco State University.

2 See *Assessing Location Suitability for more details.*

3. Historical Knowledge of Elkhorn Slough

Another driving factor for choosing the Elkhorn Slough site was the historical presence of seagrass existing in that area, as well as the natural seagrass expansion there in recent decades. From the historical research we gathered, we found that Elkhorn Slough supported ~26 hectares of seagrass in 1931 (Hughes et al. 2013). Before the 1940s, the inlet to Elkhorn Slough closed seasonally: the waterway's connection to the ocean would naturally open and close depending on the season due to sediment build-up and reduced water flow. When a harbor was built there in the 1940s, Elkhorn Slough became a permanently open estuary with continuous access to the ocean, leading to changes in the physical properties of the estuary (erosion, tidal exchange, light penetration). Simultaneously, the agricultural industry grew, causing the estuary to receive increasingly higher levels of nutrient loads and algal blooms, all of which can greatly influence seagrass restoration success as algal blooms reduce light and increase turbidity. The combination of these water quality parameters created uncertainty in restoration success. Yet, the knowledge of when and where seagrass existed historically (MacGinitie, 1935; Hughes et al., 2013) informed our restoration design and forecasting, and gave us optimism that a restoration at Elkhorn Slough could succeed.

4. Healthy Food Web

In the 1960s, the seagrass population started to decline and by the early 1980s only ~3 hectares remained. However, in the mid-1980s, due to conservation laws (U.S. Endangered Species Act and Marine Mammal Protection Act), and later efforts by the Monterey Bay Aquarium to conserve sea otter (Enhydra lutris nereis) populations, the sea otter population increased in Elkhorn Slough. The increase of the sea otter population coincided with a resurgence in the natural expansion of seagrass meadows within the estuary. The healthy sea otter population in Elkhorn Slough was a driving factor for our site selection in 2015 because sea otters play a beneficial ecological role in seagrass expansion by preying on species that feed on grazers, such as epifauna, that keep the seagrass clean and healthy by consuming algae on the seagrass. This indirect effect helps maintain the seagrass ecosystem's balance and promotes its growth (Hughes et al. 2013 & 2016). Expanding seagrass beds could be a win-win for seagrass and sea otters. In 2015, when our Elkhorn Slough project started, seagrass meadows encompassed about 15 hectares, and the sea otters were at maximum capacity in the areas that we wanted to plant in. We encourage restoration practitioners to consider factors, such as healthy predator populations or healthy algal grazer populations (snails and small crustaceans that preferentially feed on algae), as it has been shown that restoring food webs promotes restoration success (Xu et al. 2023).

Image 3: This image shows the Highway 1 bridge at Elkhorn Slough with several sea otters in an eelgrass bed. Image taken from Hughes, Beheshti, Ward. 2021. "How to" of seagrass restoration. Seagrass Transplant and Restoration Team (START).

5. Motorized Boat Restrictions

Motorized boats can harm the seagrass by leaving scars from propellers and from moorings, and they are one of the largest threats to seagrass growth in northern California areas like the San Francisco Bay (Kelly et al., 2019). In Elkhorn Slough, threats from propellers and moorings were reduced: there is an estuary-wide speed limit of 5 mph for all watercraft. There are no moorings for boats, and boats do not typically anchor overnight. Most boat traffic in Elkhorn Slough is from tourists on kayaks. Due to these restrictions, we predicted that the lack of motorized traffic in Elkhorn Slough would increase our chances of success and the survival rate of our transplanted seagrass.

6. Restoration in Marine Managed Areas

Elkhorn Slough is also the site of multiple marine managed areas: Elkhorn Slough State Marine Reserve, Elkhorn Slough State Marine Conservation Area, and the Elkhorn Slough National Estuarine Research Reserve. The protections for the Elkhorn Slough environment provided an additional layer of defense for seagrass. These safeguards influenced the level of activity and fishing traffic in the estuary, helping to prevent potential harm to the seagrass. Additionally, our location was in close proximity to the Highway 1 bridge (shown in Image 3 above). This bridge acts as a barrier preventing large motorized boats from entering the estuary and causing potential harm by kicking up sediment.

Another important feature of Elkhorn Slough is that it has several research stations on the estuary, which can be helpful for providing logistical and intellectual support. These stations included Moss Landing Marine Labs and the Elkhorn Slough National Estuarine Research Reserve, which both provided access to boats, boat launches, marine facilities, and volunteers; all aiding in our ability to perform the restoration work.

Ultimately, we believed that our restoration efforts could be successful due to the site's natural history, the recent seagrass resurgence, and enhanced food web integrity due to recovering sea otter populations.

Our point is while obstacles to seagrass restoration may exist, there may be sites within an area that are promising for restoration. We encourage everyone to not be deterred and to find these promising areas within sites.

ENGAGING LOCAL EXPERTS AND THE GARDEN STAPLE METHOD:

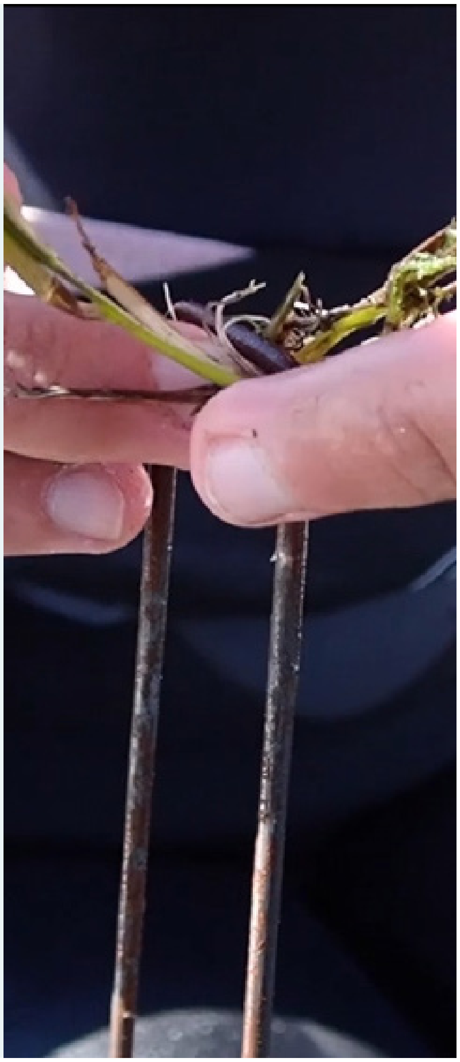
In addition to running our own preliminary tests and evaluation of Elkhorn Slough, we also engaged local experts and practitioners that were familiar with our study area who could provide guidance and recommendations based on their experience. For example, based on a recommendation from Susan Williams, a local expert involved in our project, we chose the **garden staple method** for restoration at our site, which we have successfully used for other restoration projects in the past. Throughout this handbook we will provide specific instructions for using the garden staple method because that is the method we used for this project.

NOTE:

Garden staples work well in areas with mud, sand, and fine-sand. However, the garden staple method is not necessarily the best method for all restoration projects.

Avoid using the garden staple method in places with dense pebbles and cobblestones because the staples might have difficulty going into the ground smoothly. We encourage everyone to engage local experts on what restoration methods may have worked in your study area.

In some cases, a local expert may advise you to run a pilot test to determine which restoration method will give your project the best chance of success. These pilot tests are like trial runs, helping you test various restoration methods to maximize your project's success based on your site's conditions. To determine the most effective restoration method, monitor the site regularly (bi-weekly or monthly) to observe which method keeps seagrass in the sediment the longest.



OTHER THINGS TO CONSIDER

- All restoration projects should conduct a thorough site assessment before finalizing selection of a restoration site. See Assessing Location Suitability on page 21.
- Sites that have nutrient pollution, but retain water clarity and adequate light, may still be viable areas to support seagrass growth.
- We recommend that you use a restoration method that is suited to local conditions, fits within your budget, and best helps you to plant seagrass.
- In the case of Elkhorn Slough, eelgrass transplantation was appropriate because donor beds existed nearby. It was more economical than growing seagrass from seed, which requires more infrastructure.

Project Planning

Image taken by Abbey Dias

Project Management and Timelines

Just like any other project, restoring seagrass requires resources, organizing, planning, tracking progress, and good team communication, all aimed at successfully finishing the work within a set time, scope, and budget. Below are important elements of seagrass project management. Consider this as a rough guideline that can assist you in planning the project timeline.

Essential Elements of Project Management for Seagrass Restoration:

1. SEEK AN EXPERT

To save time and money and ensure your project will be on the right track, consult with a local seagrass expert who has a track record for success. They can provide:

- Essential local knowledge, such as the historical reach of seagrass beds in that area
- Provide recommendations for specific methods
- Share insights about potential project goals
- Information about the site itself and how much funding you will likely need for your project

Generally speaking, if there is seagrass there are likely experts nearby that are typically affiliated with a local university or environmental group. Experts can assist in sharing knowledge about accessing the site correctly and can provide additional training information, if needed. You should always seek expert advice early and before you conduct a restoration to help put you on the right track to success. Many experts will happily volunteer a few hours of their time to provide recommendations and personal insights into your project design and methods.

However, if you would like to hire an expert to work on your project in the US, you should expect to pay them between ~$100-$150 an hour for their involvement.

2. DEFINING PROJECT GOALS

You can set your project goals to be as simple or complex as you like. It is important to pick goals you can achieve so you should take into account several factors that can shape your project objectives:

- Estimate your goal based on the personnel available. If you have 3 or 4 people, and they are less experienced, then planting a hectare could require 3 or 4 days. A more experienced team can accomplish a hectare in 2 or 3 days.
- Try estimating how much seagrass you will need for restoration. In Elkhorn Slough, for example, ~1,000 shoots are sufficient to restore a hectare of subtidal eelgrass. The density will change based on depth and species. However, these numbers and your estimates may change depending on the plant density data you receive from your site survey. Please refer to Conducting a Survey for Your Site on page 35 for more details.
- Establish a project goal of supporting seagrass survival by strategically planting clusters on garden staples.
- Expect a few minutes for each garden staple transplanting, depending on site's size and conditions such as water current speed, visibility, and weather. Generally in a ten by ten meter area, it would take about an hour to complete. For a hectare, this may take a day or two.
- Make sure that weather conditions are favorable for planting.

- Beyond the primary goal of increasing seagrass, additional project goals could consist of: biodiversity enhancement, water quality improvement, preventing coastal erosion, and coastal ecosystem preservation.

FURTHER READING

Check out Finding the Mother Tree: Discovering the Wisdom of the Forest by Suzanne Simard, to learn how plants can communicate with each other.

3. FUNDING AND RESOURCING

You will need funding and resources to achieve your project's goals, and your project goals will shape how much funding and resources you will need. Funding and resources are required at every stage of the project such as the planning, permitting (if applicable), site preparation, restoration, and monitoring. Consider what materials your project requires at each stage and determine the number of researchers or volunteers needed for that stage. Seek advice from an expert to address any funding questions that may arise. Keep in mind that restorations can be expensive. In 2023, restoration projects can range from $10,000 - $100,000 USD based on your project's goals, the size of your project, the amount of people on your team, future monitoring efforts, and the materials used.

4. PLANNING, DOCUMENTATION, AND TIMELINES

Generally the stages of a seagrass restoration include:

A. **Project Planning**: During this phase, you will be confirming your project's site based on an expert's evaluation and other independent measurements and observations you will gather at the site to determine if seagrass can survive there. Measurements and observations you will collect include data on light, turbidity, burrowing animals, and algal growth. Based on this information you will create a project proposal and apply for a permit. The project plan should include personnel, materials, logistics, supplies, and a timeline that will help you to successfully complete your project goals.

   The overall timeline of a project depends on factors such as permitting, weather and logistics, which can delay the start of the project. We recommend that you allow at least 6-months or more to complete these items. For more descriptions on project planning we recommend the following resources:

   - Boyer, K.E., S. Wyllie-Echeverria. Appendix 8-1: Eelgrass Conservation and Restoration in San Francisco Bay: Opportunities and Constraints In San Francisco Bay Subtidal Habitat Goals Report. 2010. San Francisco Bay Subtidal Habitat Goals Report: 50-Year Conservation Plan. San Francisco, CA.
   - Beheshti, K. M., S. L. Williams, K. E. Boyer, C. Endris, A. Clemons, T. Grimes, K. Wasson, and B. B. Hughes. 2022. Rapid enhancement of multiple ecosystem services following the restoration of a coastal foundation species. Ecological Applications 32:1–21.
   - Ward, M. and K. Beheshti. Eelgrass Restoration on the U.S. West Coast: A Comprehensive Assessment of Restoration Techniques and Their Outcomes. Prepared for: Pew Charitable Trusts by the Pacific Marine Environmental Partnership. 2021.
   - Ward, M, and K. Beheshti. "Lessons Learned from over Thirty Years of Eelgrass Restoration on the US West Coast." Ecosphere e4642, (2023). https://doi.org/10.1002/ecs2.4642

Considerations when Creating a Project Timeline:

- Note that seagrass growth and reproduction (flowering) is highly dependent on species and site-specific seasonality. However, the primary growing seasons occur in the spring-fall. For eelgrass in central California, growth rates increase in the spring with flowering occurring in the late summer. Depending on the location of your project site, **you should aim to harvest, collect, and plant seagrass slightly before or during the peak growth period.** For example, if your project is in the Northern Hemisphere, seagrass plantings should occur in February or March. If your project is in the Southern Hemisphere then September is a good month. In the Northern Hemisphere, avoid planting in fall and winter months because seasonal variations can present challenges for harvesting and transplanting seagrass, and seagrass growth. Near the equator, seasonal variations are less of a challenge, so timing may be less important.
- If your area has a high nutrient load, like what occurs in Elkhorn Slough, then plan the timing of your planting so that it avoids algal blooms. If planting occurs too late, then algal growths in April and May can smother the plantings. Plantings should occur prior to algal blooms. **We learned about the importance of timing, through trial and error, and succeeded with the above approach (see Algae section on page 22 for more information).**
- Daily weather conditions can also affect the project timelines. For example, our site conditions required us to work in the mornings since it enabled us to get more done before the arrival of the afternoon winds. Also, the timing of high and low tides should also be considered, especially if you plan to plant by SCUBA or by foot (when the tide is low).

FEBRUARY *(Northern Hemisphere)*	**MARCH** *(Northern Hemisphere)*	**APRIL** *(Northern Hemisphere)*	**MAY** *(Northern Hemisphere)*	**AUGUST** *(Northern Hemisphere)*	**SEPTEMBER** *(Southern Hemisphere)*
Begin seagrass planting	Continue seagrass planting	Avoid planting due to potential algal blooms	Avoid planting due to potential algal blooms	Flowering of eelgrass in central California	Begin seagrass planting

TIMELINE FOR SEAGRASS PLANTING BASED ON ELKHORN SLOUGH[3]

B. Site Preparation: To achieve maximum success, you have to plan for maximum success. It is recommended that you plan to restore seagrass in multiple different locations within the site because there may be unknown factors that will lead to seagrass success or failure. In this step, you will set out markers that will display the areas within the site that seagrass will be restored, and will allow for tracking of progress.

- Use markers based on your project size and goals. You can plant them in smaller, individual plots during transplanting or use them during the site preparation for larger projects (e.g., hectare or more). See Staking Markers on page 45 for more information.

C. Transplanting Process: When developing a project plan, your transplanting process should have three phases: (1) a site survey, (2) harvesting donor seagrass, and (3) transplantation. In the transplanting process, you would harvest and transplant in 24-48 hour intervals until the project is complete. Generally, the lifecycle of the transplanting process would look like this:

a. Site Survey (Total time: 30 min - 1 hr)

i. Survey time varies based on site size. Opt for a small site for quicker completion. Please see Conducting a Survey for Your Site on page 35 for more information on how to conduct your survey.

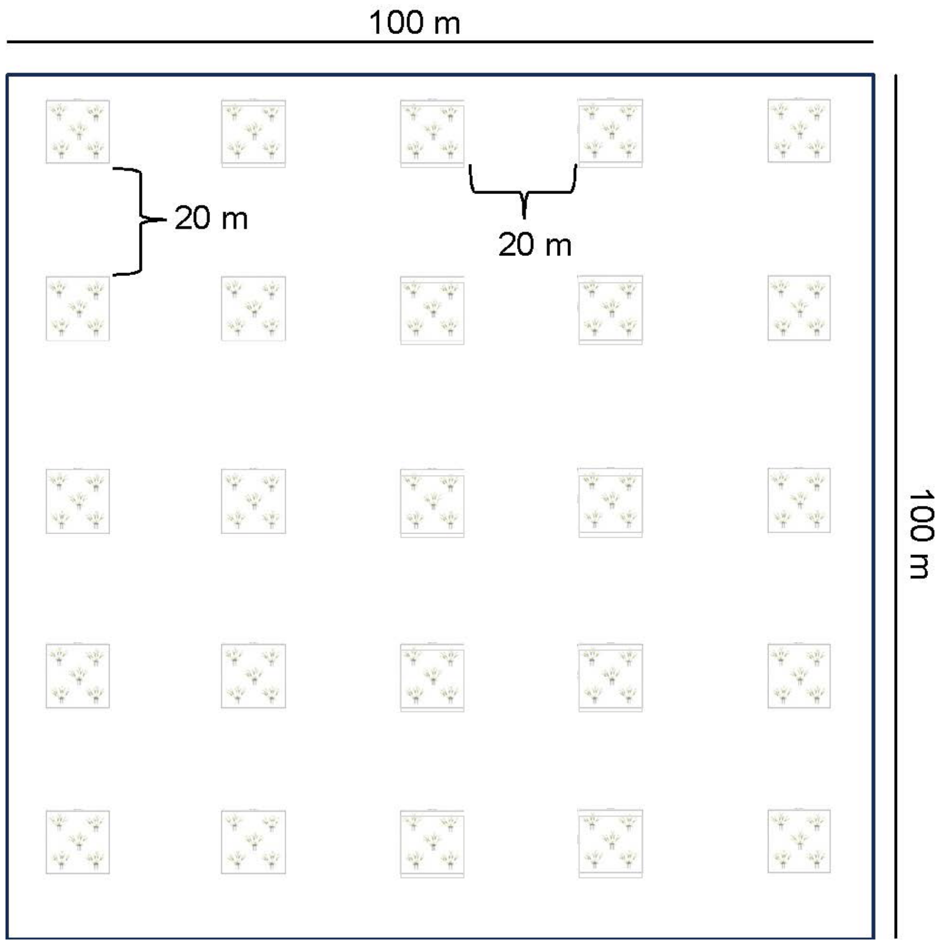
3 The timeline begins in August or September for the southern hemisphere. Not all sites will face seasonal algal blooms, and not all sites will experience the same timing of algal blooms as Elkhorn Slough. Please adjust according to your site's conditions.

   ii. This survey is conducted at the start of the restoration project, before harvesting or transplanting seagrass. The survey results determine the seagrass planting density required for your project.

b. **Harvesting (Total time varies per project size and method)**
   i. Begin harvesting from the donor bed, and if needed, store seagrass in coolers overnight. Use your harvested seagrass to transplant your site.

c. **Transplanting (Total time varies per project size and method)**
   i. This involves transporting harvested seagrass to the restoration site and the planting of seagrass. **Ideally, you should transplant within a day of harvesting as we did. At the outer limit, transplant within a week of harvesting, and keep seagrass within temperatures recommended for your species of seagrass.**

When planting restoration plots they should be spaced out in regular intervals. For example, if you are planting/restoring in a 100 m x 100 m area (equivalent to 1 hectare or 2.47 acres), then you will want to space the restored plots 20 m apart (see figure below). The number of plots planted will depend on the size and shape of the targeted restoration area, and there is no formula on the number of plots to plant. Other things that will determine the number of plots planted will be availability of resources, donor material, and time. We recommend planting restoration plots 20 m away from the nearest plot. If successful, the plots will gradually fill in empty space until there is a contiguous seagrass bed. See page 48 to learn more about determining planting densities of shoots within a plot (i.e. the distance between shoots in a star formation). For our project, we determined 25 shoots per plot was an appropriate density. (see page 43 for more information).

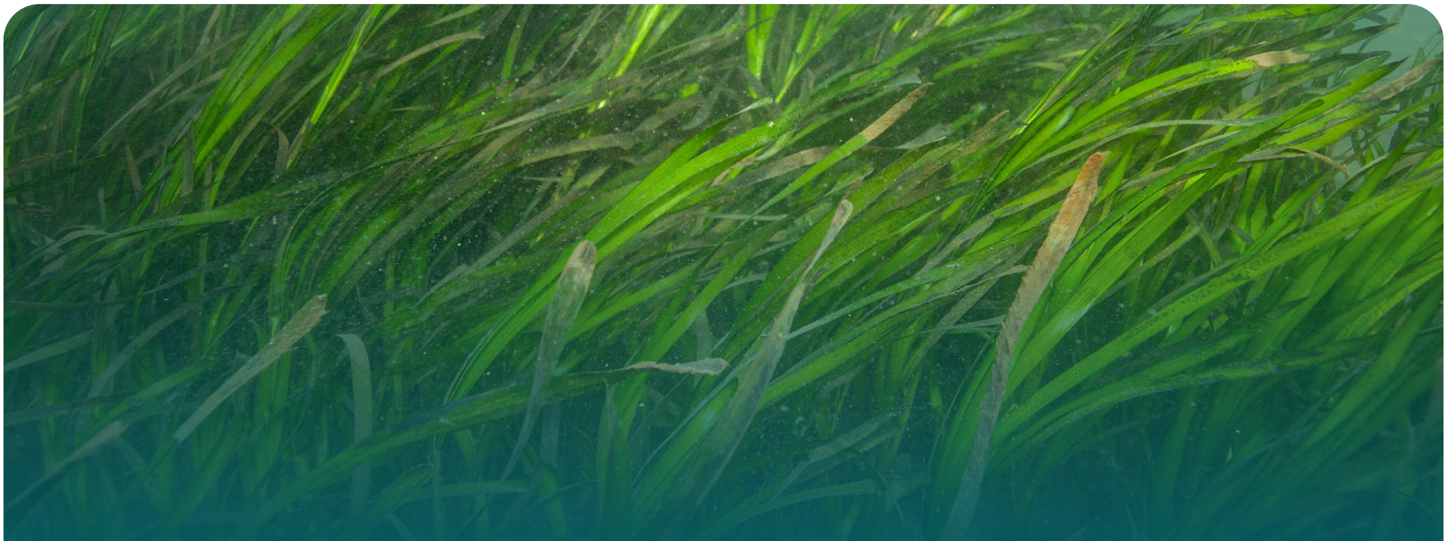


D. Monitoring: After planting, you should check on areas within your site to see how seagrass growth and expansion is progressing, and if sections are doing well or failing. The goal of monitoring is to learn about where seagrass may be expanding in successful areas and to learn about optimal site conditions for future plantings. Surveys are also useful should replanting efforts need to occur. Monitoring depends on the stage of your project and can be anywhere from weekly (such as soon after the initial transplantation) to annually.

- Larger, fast-growing seagrass (e.g., *Zostera*) grows ~1 cm a day. There is no need for you to immediately check after you plant. At the start of monitoring, consider checking weekly to observe if the seagrass has taken root or drifted away, and afterward, lengthen the duration between checks.
- At Elkhorn Slough, we chose a monitoring schedule that fit with our goals, and this led to us monitoring our site on a weekly-monthly basis, and then eventually on an annual basis.
- **Monitoring against Milestones:** Seagrass restoration is a biological process with uncertain outcomes. Regular monitoring of the areas within the site can inform where restoration has been productive. For more information about monitoring, please see Monitoring and Datasheets on page 52.

5. DOCUMENTATION AND COMMUNICATION

Communicate and document throughout the restoration process to keep team members, stakeholders, and local communities informed about the project. This helps everyone assist during and after restoration and ensures the maintenance of the restored areas.



Practical Guidelines for Seagrass Restoration Project Management

- **Timely Updates**: Provide regular updates to stakeholders, project members and the community regarding project progress, adhering to established timelines. Regular updates help keep your project on track by ensuring everyone stays informed and aligned with the project's progress and goals. Updates can be done via email, social media, or other communication methods.
- **Adaptability**: Stay flexible to adapt plans as necessary while remaining focused on meeting designated timelines. If the weather is bad or some team members are unavailable, you might need to change your plans. It is always good to build some flexibility into your plan.

Image taken by Abbey Dias

Assessing Location Suitability

Assessing the location and its suitability is vital to every restoration project. In this section you will find some helpful guidelines and insights when it comes to making sure your location is suitable for seagrass restoration.

CHARACTERISTICS OF SUITABLE SEAGRASS RESTORATION LOCATIONS

Environments that typically support seagrass growth are places that have good water circulation and contain moderate nutrient levels without an excessive amount of floating algae. Note that different locations will vary in how well they can support seagrass. For example, locations with exceptionally clear water can indicate low nutrient levels. The best way to determine if your location is suitable for seagrass planting is by understanding the characteristics that support seagrass thriving.

For seagrass to grow well, a good site should have the following characteristics:

LIGHT:

The restoration spot should have plenty of light reaching through the water's surface because insufficient light hinders seagrass growth. The light measurements should be taken immediately below the surface of the water on a sunny day. If SCUBA diving or snorkeling, make sure to measure light right under the water and above the sediment, being careful not to stir up the sediment.

- Refer to the owner's manual on specific instructions. Use micro-mol per square meter per second (μmol/m^2/s). Then hold the light sensor at the location where you want to measure light intensity and record the displayed value to determine the light level at that specific spot.
  - Sites with light levels falling below 3 μmol/m^2/s on a light meter should be ruled out as they do not meet the minimum light requirement for *Zostera marina* seagrass (Thom et al., 2008).

> **Note:**
> Not every project will have the means to access a light probe, such as the industry standard Li-Cor 193 Spherical Underwater Quantum Sensor (https://www.licor.com/env/products/light/quantum-underwater-sphere). In general, light measurements can be taken with less sophisticated instrumentation (ex. https://www.onsetcomp.com/products/data-loggers/mx2202). The light intensity at the bottom where you plan to transplant should be least 10% of the light intensity measured just above the water's surface.

Helpful tip to measure light at a new site:

- If possible, measure the light at different tidal cycles with your light reader in a seagrass bed near your site. The measurements from this existing seagrass bed will show you how much light is needed in your area.
- Conduct light measurements during peak sunlight hours, like noon, and avoid taking measurements on an overcast day.

WATER:

Turbidity is the measurement of suspended particles that obscures photosynthesis rates, which for seagrass restoration, relates to the ability for seagrass plants to harvest sunlight on the seafloor. Ideally, the water at the site should have a low turbidity level. A high turbidity level would make it difficult for seagrass to grow.

Image taken by Abbey Dias

- To understand how much turbidity is in the water, you could use a turbidity meter or light meters (see above) to help roughly measure the levels of turbidity.
- Similar to light, we suggest measuring turbidity at a nearby seagrass bed in your site to determine the turbidity levels that support seagrass growth in your area.
- If funding is available, we find that deploying water quality instrument(s) such as a Yellow Springs Instrument (YSI) sonde to directly measure turbidity at the proposed restoration site is helpful.
- Maintain Turbidity Below 10 NTU: Use a YSI Sonde, a device that measures turbidity in NTU (Nephelometric Turbidity Units), to monitor water clarity. Turbidity levels below 10 NTU ensure sufficient light penetration, critical for seagrass photosynthesis.
- See Further Resources on page 66 for resources on site-specific water quality data.

Image 4: Dr. Brent Hughes holding an algal mat at Elkhorn Slough which highlights how prolific algal production is in a nutrient loaded system.

ALGAE:

Algae competes with seagrass for space, light, and nutrients so algal growth should be low at the site. It is crucial to observe and identify the areas where algae might be present. Speaking to local experts with historical knowledge and familiarity with the area may also be helpful. They can tell you more about the algae growth that might happen during different times of the year.

In Elkhorn Slough, we chose to work in an area where algal blooms happen at certain times of the year. As a result, it was important for us to consider the timing of algal blooms in scheduling seagrass planting. For example, we learned a valuable lesson in our first year of planting because we didn't give our plants enough time to grow and protect themselves from the annual algal bloom in April and May. As a result, some of our plots were smothered by ephemeral macroalgae. **The next year, we ensured our plants had a two-month head start by planting in February and March.** The head start led to 60-70 cm of new growth, making our seagrass over a meter tall. The plants' height advantage was crucial because when the algal blooms appeared, they were not smothered by the algae.

It is common for brief macroalgal blooms to contribute to restoration plot mortality. Algae can outcompete transplanted plots for space, light, and other resources by smothering transplanted seagrass plots with algal mats like the one pictured in Image 4. For most restoration projects, we recommend that you generally avoid sites with too much algae.

CRABS:

High crab density near seagrass transplantation as well as other burrowing animals can harm seagrass growth (Hughes et al., 2013). These creatures make it possible for shoots to float away from their anchor (via your restoration method), impacting their establishment. In temperate areas, crabs can have negative predation effects on the seagrass herbivorous faunal community (snails and small crustaceans that facilitate seagrass by consuming algal epiphytes).

Photo by @pakhnyushchyy via Freepik.

- To avoid areas with burrowing animals, such as crabs or clams, you should scan the environment for sediment that does not show signs of burrowing animals, such as lots of little holes or burrows. Sediment with little holes and burrows will look similar to “swiss cheese”.
    - For temperate estuaries, we have found that intact food webs with predators, such as sea otters and predatory fish, can help prevent major disturbances to the seagrass by clams and crabs.

Image taken by Abbey Dias

SEDIMENT:

It is important for the sediment at the site to not be too coarse or too fine. When sediment is either too coarse, filled with rocks and pebbles, or too fine, it becomes difficult for seagrass to be transplanted or for their roots to anchor firmly to the substrate. Specifically, we recommend that your site has a closer consistency to sandy sediment (which is made up of larger particles) since it may have lower turbidity levels making it easier for you to transplant. Finer sediments with smaller particles, such as silty sediment, might be usable for transplanting, but they could lead to lower water quality, creating challenges.

- The most effective method to assess sediment suitability is by conducting a pilot project at the planting site. By planting a small plot of seagrass, you gauge the sediment’s adequacy in-person and see what you are working with. Difficulties in planting or observing seagrass floating away easily indicate unsuitable sediment conditions.

LESSONS LEARNED FROM ELKHORN SLOUGH

- We used a Hobo Tidbit Temperature/Light Data Logger at Elkhorn Slough to measure our light readings and water temperature. It was helpful for us, and it could be helpful for your project.
- In Elkhorn Slough, we experienced some plot failure in areas near the ocean with exceptionally clear water that were prone to seasonal algal blooms, common in the Elkhorn Slough estuary.
- Having a site with no seagrass should not deter you. At Elkhorn Slough, we pinpointed new sites that matched the ideal conditions for seagrass survival, spots where seagrass had never previously thrived, and they did well. We attribute a lot of this success due an to intact/healthy food web, which had been found to facilitate natural seagrass recovery in the estuary.

Image taken by Abbey Dias

OTHER THINGS TO CONSIDER:

- Do not exclude a site based on a single snapshot. It is worth revisiting your site at a later date or during a different tidal cycle to confirm the measurement you have taken.
- Having an existing seagrass population nearby your transplant site is a good sign of suitability since there is an increased chance of cross-pollination between a natural bed and a transplanted site. Also consider planting in locations where seagrass has historically existed.
- It is perfectly normal for sites with all the right conditions to fail.
  - Experiment with timing and location. Overtime, you can identify when to plant and where your seagrass is thriving. You can then focus efforts on planting more seagrass in those successful areas.
- Salinity levels are usually not a concern when choosing an area for seagrass restoration. Many seagrasses can tolerate a wide range of salinities. However, if extreme changes occur, such as a site going from oceanic salinities to pure freshwater; or locations going hypersaline (>35 ppt) then this could present a challenge for establishing new seagrass.
- With climate change, and more specifically ocean warming, optimal areas to grow seagrass may have changed from their historical boundaries. Climate change is also known to disrupt seagrass health and can influence restoration results.
- If your team has technical experts who can create bathymetric models, you can use these bathymetric models to identify ideal spots for planting seagrass, which can narrow down site selection and specific plots for planting.
  - At Elkhorn Slough, we utilized side-scan sonar data to measure the depth of the water. This information was compared with known areas in the slough that have the perfect depth for the plants. We matched the amount of light they require with the light received in nearby donor beds.
  - We also relied on these bathymetry models to avoid areas that had a lot of scouring. Scouring makes planting difficult because the strong water displaces sediment, exposing and harming seagrass roots.
  - The areas we chose with the help of the bathymetry maps included areas with more depositional sediment and had ample amounts of light.
- High current velocities can be problematic for establishing new seagrass plots due to dislodging. The following steps might help:
  - A simple way to test whether there is a fast current in your area is by creating a small float made of lightweight objects and observing how quickly it moves away. The quicker the speed of the lightweight object, the faster the current.
  - If you observe that aquatic plants struggle to survive in areas with high current speeds, it is probable that the currents at the site may not support new seagrass growth there.
  - Areas with high current speed should not deter you from transplanting if you observe seagrass living there. If you restore in an area with fast currents, we recommend that you use 45 cm garden staples to help secure the plants into the sediment.
- For more information about permitting, see Appendix A on page 59.

Assembling a Team

Restoration projects come in all sizes and team make-ups and are often determined by goals and funding. If your team needs local experts and scientists, it is possible a considerable part of your funding might be allocated to them.

- You will probably need to hire researchers or experts to assist in organizing and planning (in the US in 2024, budget $100 - $150 an hour for 5-10 hours a week for project planning for 6 months).

ELKHORN SLOUGH CASE STUDY

This case study was implemented to conduct research and plan plantings. A project focused on implementation, and not research, would need fewer measurements and less work effort.

Between 2015-2016, we planted 117 0.25m^2 plots (29m^2 total), in 2 main efforts: In 2015, we planted between April and May, and in 2016 we planted during February and March.

All harvesting and transplanting was done with SCUBA, with the help of 21 volunteers and 3 seagrass experts, all of whom were SCUBA certified.

In any given transplantation or harvesting session, we relied on 6 - 8 people consisting of:

- 1 boat (we used a 12-foot small boat), with a boat driver/navigator, 2-3 SCUBA divers, and someone onboard to help coordinate with the boat driver, eelgrass transplants, and SCUBA divers in the water.
- Our project had higher staffing levels because it had multiple goals of training and implementation. At minimum, you will need four people: a boat driver, someone to support the boat driver, and then two SCUBA divers.

Over the course of our project a total of 14 people worked in the field at the Elkhorn Slough restoration. Experts worked 20-40 hours weekly (depending on the week of field activities), while boat drivers and volunteers contributed 30-40 hours weekly (usually only on weeks of harvesting and transplanting). This hourly breakdown accounts for responsibilities for pre and post-site logistics, on-site management, active transplanting and harvesting.

We worked within the context of 48-hour cycles, with the first 24 hours being devoted to harvesting seagrass and then the next 24 hours being devoted to transplanting seagrass. Once the transplanting from the harvested seagrass was complete, we would reset the cycle over. We stuck to this 48-hour schedule because seagrass is best able to survive during this period, and it still allows your team the flexibility to complete their tasks.

However, work was not continuous within 48 hours. Work started around 7am-8am and usually lasted until early afternoon. In the early afternoon, sometimes it becomes too windy to work efficiently. Additionally, work hours depended on the tides since we used scuba gear, and we needed high tides to do harvesting and transplanting from the boats.

With our full team working at the site, working 3-4 hours in ideal site and tidal conditions, we could either harvest enough seagrass to fill or transplant seagrass for approximately 5-10 0.25m^2 plots within every 48-hour cycle.

On our team, we also relied on many unpaid positions such as volunteers and undergraduate students to help us with our project. In addition to the experts we used ten volunteers to support our project goals. The actual number of roles necessary for a team varies per project, but a good way to understand how many roles you need for your team is to divide the roles into supporters and transplanters. Generally, we recommend that there should be one or two supporters (excluding the boat driver) for every transplanter. In the case of a smaller restoration team, small teams may have to combine transplanter and supporter roles into one.

Image 5: A team of volunteers processing harvested seagrass. Image taken from Hughes, Beheshti, Ward. 2021. "How to" of seagrass restoration. Seagrass Transplant and Restoration Team (START).

Below are common examples of different team roles found in a seagrass restoration. You might find that some of these example roles and their duties do not fit your project goals, and that is OK. You should customize your project team based on roles that support your project goals and align with your available financial resources.

PROJECT LEAD

A project lead is essential for planning logistics, budgeting, permitting, coordinating schedules, organizing supplies, supervising, leading trainings, troubleshooting, overseeing safety and that safety protocols are in order, and ensuring proper documentation and waivers. The project lead also guides project coordination, data curation and analysis, and reporting for the restoration project. They are instrumental in being an intermediary between the local community, on-the-ground partners, and those on the project.

- If a restoration project is large, implementing two project leads could be useful in dividing up tasks and maximizing efficiency.
- Depending on whether the purpose of your project is to conduct research or not, several project lead tasks like leading publications may not be applicable.

TRANSPLANTER

The transplanter's main focus is to make sure that the seagrass is gathered from donor beds and is correctly planted into the ground. Their work will involve them physically being in the water and sediment, planting the seagrass. Transplanters will work closely with supporter roles that will assist them to transplant the seagrass into the sediment. Transplanters will be in-charge of their individual planting efforts.

SUPPORTER

Supporter roles generally refer to the people who are not directly involved with the seagrass planting itself. They are meant to provide additional help to those that are transplanting the seagrass or those closely associated with the transplanting. Including support roles in your project helps fill expertise gaps and ensures a smooth and efficient project at given times. Common support roles include people that organize and trim shoots, boat drivers, spotters for the divers, and people collecting measurements of seagrass.

DIVE TEAM

SCUBA divers are commonly used in transplanting areas that are in water deeper than 1.5 meters. Not every restoration will call for a dive team, but if the project does then all divers must be SCUBA certified. Since light and current conditions may change quickly at a site, divers should have experience diving in low-visibility conditions and have excellent buoyancy control. If your seagrass restoration is primarily geared towards conducting research, we highly recommend having SCUBA divers that have subtidal research experience.

NOTE:

If you are conducting your restoration as part of an affiliated university or other organization effort and using SCUBA, you must make sure all participating divers are certified under their specific guidelines (e.g., AAUS).

DATA RECORDER

This role includes assisting with the measurement of seagrass or assisting someone with seagrass data, GPS data and navigation, and subsequent data entry of any field-collected data. Depending on the scope of your project this particular role might not be relevant for your project.

IMPORTANT

- All restoration efforts require financial resources for team compensation and their supplies. When designing your project, and before applying for a permit, please take into consideration what resources are available or needed for your project to be successful.
- Create a team based on your project goals. Generally, if your goal is to plant seagrass in a large area, it is recommended to have a large team to assist you. Likewise, if your goal is to plant seagrass and collect scientific measurements for research, we generally recommend that you have experts on your team to assist you.
  - Assembling a team of seven is helpful for most projects because it will include a project lead, and several people to plant and harvest the seagrass.
  - Team sizes may also vary depending whether you are in a boat, kayak, or walking to your site.
- In the assembling of your team, it is important to ensure that everyone signs a waiver. We encourage the use of waivers in seagrass restoration because they help protect everyone involved by explaining risks and making sure everyone understands and accepts them before restoring. Waivers help minimize liability in case something unexpected happens. Before starting physical restoration work, ensure that waivers are signed by all participating in the seagrass restoration and collected by the project lead.
- It is recommended to assemble your team well in advance before the actual seagrass transplanting to make sure you have enough people to help with transplanting. Planning ahead helps set a specific transplanting date and assigns roles in advance.
- If you are using SCUBA, we highly recommend two support roles:
  1. A boat driver
  2. A second person who remains on the boat as a safety precaution and helps with coordinating efforts with the divers (this can be the Supporter). Based on their abilities, these two supporting roles could be combined, however in our project, it was simpler to have a dedicated boat driver, allowing the support person on the boat to more effectively assist the divers.
     - To plant quickly over a large area with SCUBA or snorkeling, we recommend that you scale up your team size and have multiple boats that can assist in transplanting efforts.

Personnel Training

Training your team is an important step in conducting a seagrass project because it ensures everyone on the team understands what to do and how to do it correctly.

Depending on the expertise of your team members, they will likely need support and training to perform their tasks. Training is crucial because it involves transferring expert knowledge to others and ensuring everyone works safely and efficiently. You can conduct most training on-site and it does not take long.

To help ensure the success of your restoration project, some training can be done off-site beforehand.

FIRST AID AND CPR TRAINING

Attend a local community course or find information online to learn First Aid and CPR. Having at least one person on-site with these skills ensures quick help in emergencies.

DEBRIS REMOVAL

Debris prevents light from reaching seagrass, and needs to be removed in a restoration project to increase seagrass habitat. At times, it might be essential to clear debris from a site to facilitate better growth conditions for seagrass. Examples of debris that you and your team may come across might be old fishing gear, moorings, and chains.

Note: some seagrass restoration might focus exclusively on debris/trash removal as the goal to stimulate seagrass expansion.

SCUBA DIVING CERTIFICATION

Ensure all divers working on seagrass projects using SCUBA gear have up-to-date certifications. Some restoration divers might need AAUS certification if the project is associated with a university or other entity requiring a higher level of certification beyond Open Water. To become SCUBA certified, we encourage you to find information online for SCUBA diving certification classes near you.

Photo by @EyeEm via Freepik.

Logistics and Supplies

Arranging logistics for a seagrass project is vital as it ensures the smooth coordination and timely delivery of resources, equipment, and personnel to the project site. Effective logistics management is crucial and will allow you to make sure the correct materials and people are at the site on time, improving the project's chance of success, while also ensuring maximum safety. Below are a list of some key things to consider when coordinating your project:

SEASONALITY, WEATHER, AND TIDES

Being mindful of time of year, changing weather conditions, and tides is crucial for ensuring a smooth and safe seagrass restoration project

- We recommend harvesting, collecting, and planting seagrass shoots during the early spring because seagrasses are likely to flower during late spring/summer.
- It is important to factor in the local blooming season of algae (if present) at your site. Algae blooms harm newly transplanted seagrass, if they occur before the seagrass establishes a full canopy.
- We suggest that you conduct your restoration during a few days of good weather, specially a stretch of time that is:
  - Sunny (better light penetration/visibility in the water)
  - Calm wind conditions
  - Low chance of precipitation
  - Low current speeds
  - A low tide if you are walking to your site or a high tide if you are using SCUBA

TRANSPORTATION AND TIMING

Taking into account transportation of materials and personnel is a key factor to keep in mind when dealing with restoration logistics. For example, some areas are nearshore and are easily walkable, while some sites require the use of a boat to get to them. Make sure you address the questions below to ensure smooth transportation and clear timing for your project, and then clearly communicate this information to everyone on your team.

- How is everyone getting to the site?
- How are the materials getting to the site?
- What time should everyone arrive and what time should everyone expect to finish?
  - At Elkhorn Slough, we arrived early in the morning, around 7am-8am since the site conditions were calmer at this time (i.e., less windy) and left if winds increased in the afternoon.
- Where is the harvested seagrass going to stay?
  - The harvested seagrass should stay with the team member that has enough space to store it, and they should store it in a cooler so that the seagrass remains cool (ideally between 39 - 45 degrees Fahrenheit). The harvested seagrass can also be stored at a nearby facility where the shoots can securely remain in a cool location. These people will be in charge of bringing the harvested seagrass to the site.

PERSONNEL

Organizing your team and enabling them to perform effectively is an important step in the logistics process. Here are some example questions and information that can help focus your logistical efforts:

- Are there enough people to assist in the seagrass harvesting and transplanting?
  - In total, we had nearly 30 people (the majority on a short-term basis) assist us in harvesting and transplanting seagrass for our Elkhorn Slough project.
- Will there be enough people available for the transplantation?
- Do personnel possess the necessary skills for seagrass harvesting and transplantation?
  - Since our team was composed of several experts, we were able to share our knowledge with volunteers who did not have the same levels of experience of seagrass harvesting and transplanting.
- Have safety protocols been discussed and understood by all team members?
- Have all team members undergone relevant training for seagrass restoration techniques and monitoring?
- Will there be additional supplies? If so, which ones?
  - Bringing extra supplies like duct tape or flagging tape can be helpful at the site, even if you don't need them right away.

LOGISTICS FOR RESTORING SEAGRASS WITH SCUBA

Before starting SCUBA-based restoration you should answer logistical questions in advance. Here are some example questions and information that can help focus your logistical efforts:

- Is SCUBA gear working properly and well maintained?
- Is there enough diving gear for those who are transplanting? Are they certified? Are the divers comfortable with low visibility, and do they have adequate buoyancy control?
- Will there be rentals of the gear involved? If so, how much? How much does it cost?
- Will there be enough people to act as support for those divers? Does everyone on the support team have a role to play in the boat or onshore?
- Has the boat (if needed) been arranged, and is it in good working order?
- The optimal timing for SCUBA-based seagrass restoration is:
  - During a robust spring tide cycle for improved water circulation.
  - During incoming tides, which are favorable for restoration efforts due to better visibility.

LOGISTICS FOR RESTORING SEAGRASS ON FOOT

Walking or wading out to a seagrass bed represents one of the most cost-effective and direct methods for reaching a site and conducting a restoration. However, restoring on foot involves its own logistics. Here are some example questions and information that can help focus your logistical efforts:

- How many people are needed to harvest the seagrass?
  - Number of people depends on the size of the restoration area. A larger area requires a larger team to ensure the project is performed quickly, efficiently, and safely. Conversely, a smaller project area requires a smaller number of people.
  - If possible, work in pairs when harvesting and transplanting to be efficient and avoid accidentally trampling seagrass roots.
- What are the weather conditions of the day?
  - We recommend that your restoration takes place in calm conditions in order to assist with transplanting efforts.
  - Typically, the ideal time for seagrass restoration on foot would be during a low tide of a spring tidal cycle. This would allow you to walk out easily to a site since the water level will be at its lowest. A good time to conduct seagrass restoration on foot is during the outgoing tide, as you can maximize time using both the ebb and flood around the low tide.
  - Sometimes your site might not have sufficient space to avoid walking on seagrass. Try to maximize each trip across the seagrass beds or use naturally occurring bare patches within the seagrass bed when possible.

SUPPLIES AND MATERIALS FOR THE RESTORATION

We recommend that every restoration project generates a “must-bring” list of items ahead of the restoration. You might have some things, but you will probably wish you brought more stuff to the site. Please refer to our Appendix B on page 59 to see the entire list of recommended items. The number of materials for each restoration project varies, but the list in the Appendix B should give you a good idea of what materials you might need.

SAMPLE BUDGET

The project budget largely depends on the size of the area being restored and the number of experts or volunteers involved. A project budget for a seagrass restoration can range from $10,000 - $100,000 USD based on these characteristics. Please refer to Appendix C on page 60 for an example of a typical budget you might use for a restoration project similar to the size of our project for Elkhorn Slough.

THINGS THAT COULD AFFECT YOUR BUDGET

- Quality and quantity of materials that you purchase
- SCUBA vs non-SCUBA
- Site Access - if the site can be accessed by foot or if a boat is required
- Size of restoration project and the number of people needed

Restoration

Conducting a Survey for your Site

A site survey is essential for restoration projects because it provides information about the number of plants to harvest for transplantation at the specific depth of the site and what the planting density should be for your site. Your site survey should be conducted near existing seagrass beds at your site at the same depth that you wish to transplant. We advise you to conduct a survey of your site before you harvest any seagrass.

If your site does not have seagrass beds to survey, conduct a survey in a nearby seagrass bed that meets similar environmental conditions as the targeted restoration area (depth, temperature, sediment type). For example, if your site is located in deep waters (e.g., 4 meters), your survey should be conducted at this same depth at the nearby donor seagrass bed. The observations recorded at the same depth as your restoration are important because this data will tell you the optimal plant density for that depth.

If a potential restoration area lacks seagrass beds in close proximity, but contains all the right conditions to support seagrass growth listed in the Assessing Location Suitability section, it may still succeed. We recommend piloting 3-4 plots in different locations within the restoration area to see where planting may be the most productive.

Image 6: A SCUBA diver is using transect tape to conduct measurements at a restoration site in California. Image taken from Hughes, Beheshti, Ward. 2021. "How to" of seagrass restoration. Seagrass Transplant and Restoration Team (START).

STEP-BY-STEP INSTRUCTIONS FOR CONDUCTING A SITE SURVEY

Follow the instructions below to conduct a site survey. Please see Appendix D on page 61 for more information about what materials are needed for conducting a site survey.

- Start your survey by placing a transect tape in the center of the donor bed (try avoiding edges), matching the depth where you plan to plant.
    - The length of the transect will be dependent on the size of the seagrass bed. The goal is to count shoots in 8-10 50 cm x 50 cm quadrats in regular intervals (e.g., every 5 meters) along the transect. The average among these quadrats (pvc squares) will give the planting density and allow you to estimate the harvest quantity.

- Walk or SCUBA dive along the transect tape and record the seagrass densities at regular intervals and record the data systematically.
    - To measure seagrass densities, you will count how many healthy seagrass shoots are in that regular interval by using a quadrat. If there are a lot of plants in that area, you can make a rough estimate of the number of shoots within that space.
    - **IMPORTANT:** Note the depth gradient along the transect while doing these recordings because it will determine the planting depths for your project. If the depth changes, you need to take note of the amount of seagrass growing there.

- Based on your survey data, calculate the target densities of seagrass for your project.
    - This information will guide your harvesting and transplantation efforts. For example, if you record or estimate that there are on average 100 seagrass shoots in 50 x 50 cm plots in a given interval at your depth at the donor site, you should aim to harvest 100 seagrass shoots in plots in the restoration area.

THINGS TO CONSIDER

- For your project's site survey, it is usually good to use 100-meter transect tapes, depending on the size of the seagrass bed.

Harvesting Shoots from the Donor Bed

Harvesting seagrass shoots from a nearby donor bed is one of the most important steps in the restoration process (Van Katwijk et al. 2016). Nearby donor beds hold seagrass species that are best adapted to the area. You should ensure that you are transplanting only native seagrasses. If you have questions about native seagrasses in your area, please contact a local expert or research online.

The plants you harvest will be the ones used in your transplanting. Therefore it is critical that your team follows the instructions in this section to ensure that seagrass is harvested correctly. If you are an expert, please share your knowledge to help volunteers follow procedures accurately.

Image 7: Dr. Brent Hughes harvesting seagrass in Elkhorn Slough in 2021. Image is captured from Hughes, Beheshti, Ward. 2021. "How to" of seagrass restoration. Seagrass Transplant and Restoration Team (START).

Properly harvesting, collecting, and storing shoots reduces damage to the donor bed and ensures healthy shoots are transported to the restoration site. The donor bed holds crucial information for research projects or restoration plans that utilize various monitoring efforts. This information can serve as a benchmark for success in your project later on. For more information about how to conduct measurements in the donor bed for monitoring, please see our section on Monitoring and Datasheets on page 52.

During the harvesting process, it is important to try to harvest the amount of seagrass you need for the transplanting process lined out in your project plan. Stick to this number as it is essential for achieving your goal. If you find your original number is very different, it is okay to change it. Just update your project goal and design accordingly.

UNDERSTANDING SEAGRASS ANATOMY

Before harvesting seagrass, it is important for harvesters to understand the seagrass' underground parts, such as the rhizome, shown in Image 8 below. The rhizome is a thick underground horizontal stem, similar to a potato or ginger root. Recovering the rhizome during harvesting helps the plant adapt after replanting. Understanding the anatomical structure of seagrass helps volunteers become familiar with the plant, enabling more effective harvesting and transplanting efforts.

Image 8: A team member showcases seagrass anatomy, specifically the rhizome. Pink box added to highlight the seagrass rhizome. Image is taken from Hughes, Beheshti, Ward. 2021. "How to" of seagrass restoration. Seagrass Transplant and Restoration Team (START).

Additionally, one part of the anatomy that your team should be familiar with is the seagrass' meristem, which is shown in Image 9 with pink arrows. A seagrass meristem is a special part of the plant that helps it grow. It is found at the intersection of the rhizome and the shoot. This area, known as the sheath, contains cells that divide and create new cells, allowing the plant to grow longer and produce new leaves. In the harvesting process, it is crucial to trim the seagrass leaves above the meristem. This helps initiate the growth of the harvested seagrass when they are transplanted. See steps 7 and 8 in How to Harvest Shoots for the Restoration for more information.

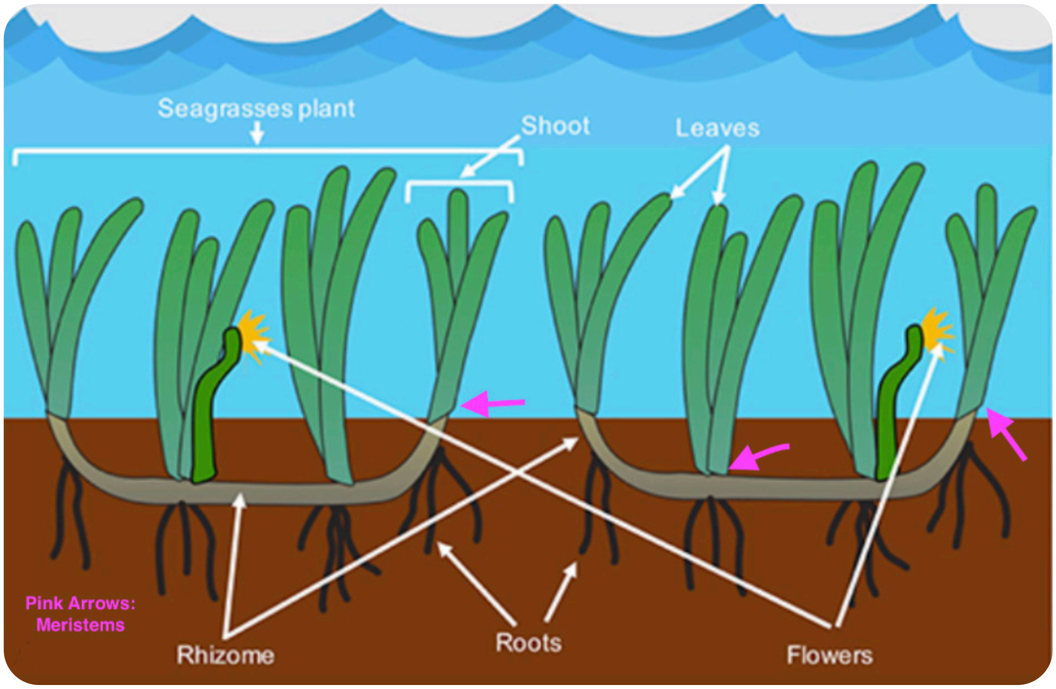


Image 9: This diagram shows the basic structure of seagrasses. (Source: Wikimedia)

The instructions below apply for all restoration methods including diving with SCUBA gear, snorkeling, or walking. If the water is deeper than 1.5 meters, using SCUBA is recommended because it is faster and more efficient than snorkeling. SCUBA divers can cover a hectare of seagrass harvesting and transplanting in just a couple of days, whereas snorkeling will take longer. If snorkeling is chosen, the person must stay close enough to the surface and the sediment to plant the seagrass, usually within arm's length.

HOW TO HARVEST SHOOTS FOR THE RESTORATION

1. Arrive at the donor bed with your team and with your necessary supplies nearby:

   - Cooler
   - Mesh bags
   - Shears/scissors
   - Monitoring equipment

2. Begin by filling the cooler brought for seagrass storage with seawater from the site. The amount of seawater inside the cooler should be enough to submerge all the harvested seagrass. Your cooler can support as much seagrass as it can fit in it. It may be necessary to add more seawater to the cooler as it is filled with seagrass to ensure the seagrass remains partially submerged.

   > **NOTE:**
   > The grass just needs to stay cool and moist. This can also be accomplished with wet towels. The idea is that if it is a cold day they just need to stay damp. On hot days, towels can be switched out, and ice packs can be used if it gets very hot. If grass is not going to be transplanted within 1 day of harvesting, then having them submerged in seawater would be necessary. They can be kept in a cooler for no more than 1 week, and if conditions are maintained.

3. Before harvesting seagrass, have your mesh bags ready to store the harvested seagrass shoots easily. Carrying mesh bags will also help minimize the number of trips needed to transfer seagrass from the bags to the cooler. Fill your mesh bag with as much seagrass as it can comfortably hold.
   - Harvest only the amount of seagrass that can be planted within the allocated planting time.
   - If using the garden staple method, note that planting one garden staple with several seagrasses will take a few minutes to complete.

4. When considering where to harvest seagrass from the donor bed, remember there is not a specific "starting place".

5. Choose a single healthy shoot for harvesting. A healthy seagrass shoot displays a green color.
   - If the focus is on recording the donor site for your project plan, it is best to take measurements or photos of the donor bed while identifying healthy shoots.

6. Start by gently placing your hand into the sediment under your target shoot. The goal is to grab the rhizome, not the shoot. A quick, gentle pull should remove the rhizome with the shoot intact. Inspect the rhizome to ensure it is at least 5 cm and ideally no more than 10 cm, and that the shoot is still firmly attached to the rhizome. It is okay if some sediment comes up with the seagrass shoot, but avoid collecting too much sediment since it will take up more space in your cooler; you can shake off the excess sediment. While tools like weeders, garden plugs, or handheld utensils can help, simply using your hand may be the easiest method. If you use a tool, be gentle and avoid applying too much force.

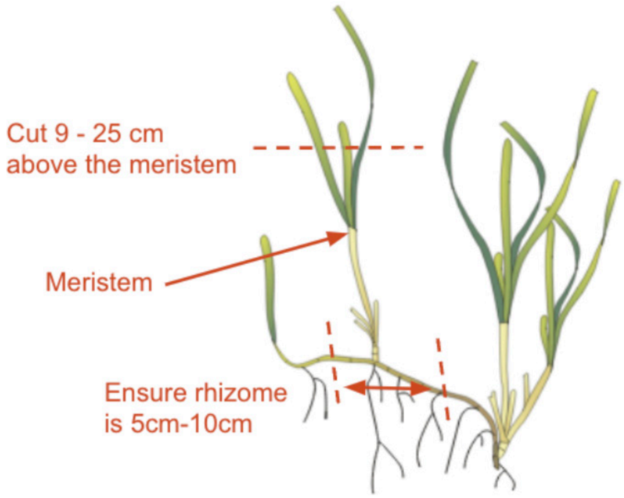


Image 10: This image indicates where to cut the seagrass. Cut above the meristem and ensure the rhizome is between 5cm-10cm. Cut rhizomes exceeding 10cm (Source: Vecta.io)

7. Immediately after harvesting the shoot, start trimming the seagrass' leaf carefully **above the meristem to 25 cm.** Cutting meristems can be done quickly and uniformly by matching up meristems of other shoots (e.g. 15 shoots at a time).
   - If the harvested rhizome is more than 10 cm long, **it is recommended cut it to a length between 5 cm - 10 cm.** Cutting it to this size makes it easier to transport in your cooler and transplant in the ground.
     - You can efficiently trim long seagrass rhizomes by aligning multiple seagrass strands together and cutting the rhizomes simultaneously to a length between 5cm and 10cm.

> **NOTE**:
> The specific level of trimming above the meristem at your site should be customized to what best fits in your cooler and what best works for your project.
>
> **NOTE**:
> In areas where seagrass is relatively short (< 50 cm) it might be unnecessary to trim shoots.

8. The seagrass' meristem is where the plant's roots meet the stem, and it is also where new shoots of seagrass grow from the stem. Cutting above the meristem at the same height does several things:
   - It makes it easier to move the seagrass shoot to your site, and the plant then signals itself to regrow, such as the re-stimulation of new growth in rhizomes and root hairs, jumpstarting its growth after transplantation.
   - All planted seagrass will all be the same height, facilitating monitoring.
   - Cutting seagrass removes epiphyte material from the seagrass. Epiphyte material on seagrass refers to tiny plants, algae, or small creatures that live on the surface of seagrass. They attach themselves to the seagrass leaves and stems, sometimes forming a layer. While some are helpful, too many can affect the seagrass's ability to grow by blocking sunlight or taking up space.

> **NOTE**:
> Cutting below the meristem will kill the plant. Please refer to Image 10 above for more information on where the meristem is located.

LESSONS LEARNED FROM ELKHORN SLOUGH:

- The extent of each seagrass cut varies, but it is common to remove a significant portion of the seagrass leaf. For instance, when harvesting seagrass in Elkhorn Slough for new sites, we would cut down seagrass that was almost two meters long to 25 cm. Reducing the seagrass to this height made it easier to handle, allowed us to monitor them more easily in our experiment due to their uniform size, and enabled them to still receive sunlight, even during the yearly algal blooms in Elkhorn Slough.
- If enough staff is available, having one member of your team cut the harvested seagrass to a uniform and manageable size can be helpful. Additionally, they can directly place it in the cooler.
- All the cut trimmings of the seagrass leaves can be left at the site or responsibly disposed of on land if resources are available to transport them back.
- Gathering a thousand shoots in just half an hour is achievable with practice and efficiency. Those thousand shoots would be a good start to restoring 1 - 2 acres of area.

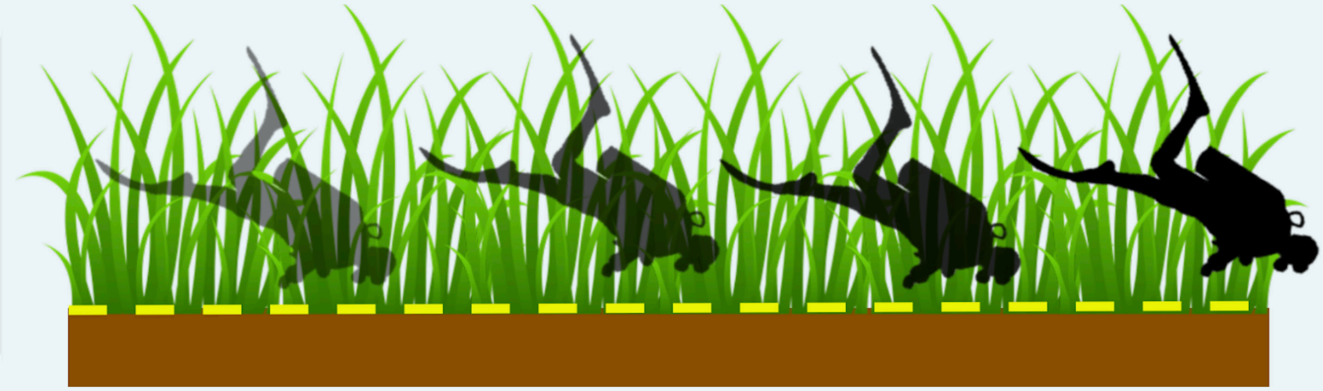
9. After collecting and trimming the seagrass, place it in the cooler filled with seawater or moist towels. Typically, seagrass can stay out of the water for a few hours if it stays moist. In a cooler, seagrass can survive around 24 hours or longer if cool conditions are maintained.
    - In Elkhorn Slough, we placed around 500 to 600 shoots that were evenly cut at 25 cm into large Igloo coolers. We recommend that you consider the size of your cooler and the scale of your project ahead of cutting harvested seagrass.

Image 11: Dr. Kat Beheshti transfers recently harvested seagrass into a cooler filled with seawater from Elkhorn Slough in 2021. Image is captured from Hughes, Beheshti, Ward. 2021. "How to" of seagrass restoration. Seagrass Transplant and Restoration Team (START).

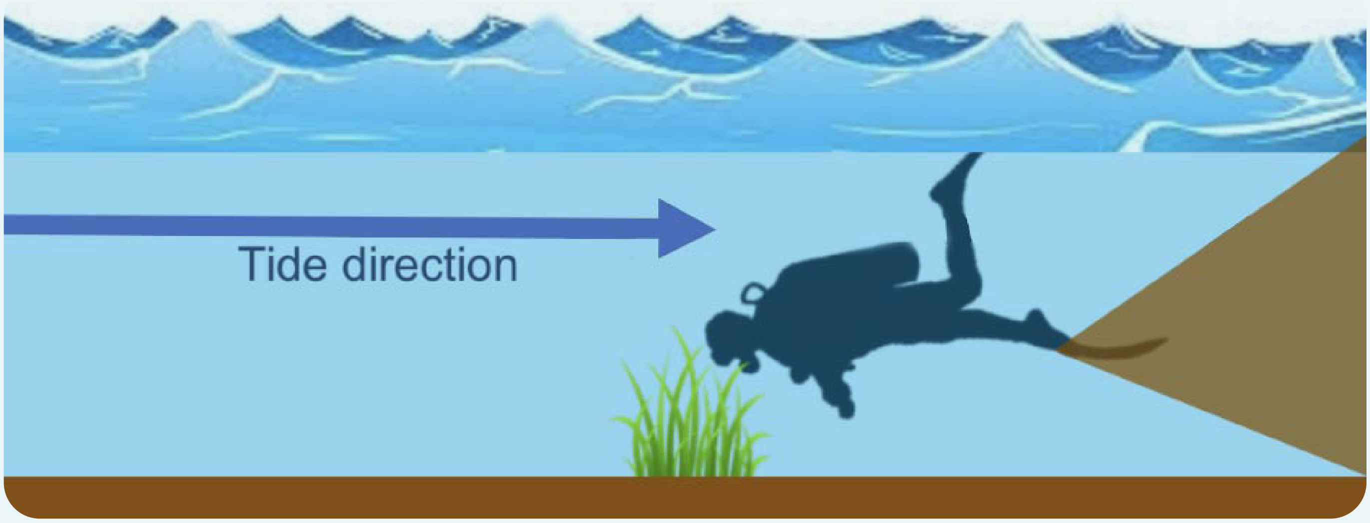
Repeat steps 5-9 until the amount of harvested seagrass corresponds with the time allotted for replanting.

THINGS TO BE AWARE OF

- IMPORTANT: Never harvest all shoots from a single area of the bed. To avoid overharvesting, use the Kick-Kick-Kick method. It can be used for both restorations on foot and SCUBA. This method involves harvesting one shoot, placing it in a mesh bag, and then moving to a new section of the donor bed by kicking with SCUBA flippers (or walking). Every ~3 meters (about three kicks with fins), a new shoot is collected. This process should continue until no more than 5% of the existing shoots in the donor bed have been harvested (see below). When using this method, swimming or walking in lines, similar to mowing a lawn on land, ensures even harvesting. This approach protects the donor bed from overharvesting and enhances genetic diversity in the harvested shoots.



- IMPORTANT: Only harvest as much seagrass as you can transplant in a day and no more than 5% of the donor bed.
  - The number of seagrass that can be transplanted in a day can be influenced by the time spent harvesting it.
  - The 5% to harvest from the donor bed can be determined by using the information collected during the site survey. Refer to Conducting a Site Survey on page 35 for more information.
- During SCUBA harvesting, kick in the direction of the tide's movement to ensure that anything stirred up gets swept behind you, away from the harvesting area. Maintain this same SCUBA movement technique during the restoration process.



Preparing the Shoots and Transplanting

The instructions to prepare and transplant seagrass are the same whether snorkeling, SCUBA diving, or walking to the site. For key details on the differences expected during transplantation for snorkeling, SCUBA diving, and walking, please refer to the following sections on page 49-50: Transplanting by Foot and Transplanting with SCUBA and Snorkeling.

Substitute the example numbers we have provided from Elkhorn Slough with specific local data about plant densities you have collected in your area and scale your numbers up or down based on localized data. Refer to Conducting a Survey for Your Site on page 35 on how you can learn more about the right plant density for your site.

Before seagrass is transplanted you must prepare your seagrass bundles. We recommend that you prepare the shoots into bundles for transplanting. Following the Step-by-Step Instructions for Preparing Seagrass Shoots on the next page will enhance the overall efficiency of the transplanting process.

LESSONS LEARNED FROM ELKHORN SLOUGH

At Elkhorn Slough, we prepared bundles of up to 50 shoots at a time for quicker and more efficient planting in plots. We also chose 50 shoots per bundle because it best matched the planting density for our area and the depth we were planting in. Out of these 50 shoots, 5 shoots are used per garden staple, and this resulted in 10 transplanting pits per bundle, enough for two restoration plots with 25 shoots per per 0.25 m^2 plots.

For your project, you should customize the amount of seagrass per bundle and garden staple with something that best represents the planting density data gathered in your site survey. Additionally, it's important to be mindful of the length of garden staple (25 cm, 30 cm, 45 cm, etc.) needed to transplant at your site. For example, at Elkhorn Slough, longer garden staples (30 cm- 45 cm) were used because the sediments in some areas consisted of a mix of coarse sand and fine grains. This choice gave the seagrass best chance of anchoring to the sediment for that area. However, in other locations, where coarse sand is mixed with pebbles or cobbles, shorter garden staples (25 cm) were useful to account for large rocks and bedrock buried under the sediment. Refer to Assessing Location Suitability on page 21 for more information on sediment.

STEP-BY-STEP INSTRUCTIONS FOR PREPARING SEAGRASS SHOOTS

1. Go to the cooler where the harvested seagrass is stored. Handle seagrass rhizomes carefully from the cooler to prevent breakage, as they can easily break. Remove a batch of seagrass to create a bundle.
    a. If a seagrass shoot looks weak (i.e., discolored or decaying), we recommend discarding it and not using it for your bundle.

2. For each seagrass, scissors may be required to trim any unexpected tangles or manage unruly seagrass in the cooler for easier planting. Discretion should be exercised when deciding whether and how much to trim, since these were already trimmed before being put into the cooler.
3. Next, organize the shoots into bundles that best match the planting density for your area (i.e., 25, 50, etc.). Creating a bundle involves grouping all the seagrass together with the roots in one direction and the leaves and stems extending the other way. Secure each bundle loosely with a zip tie at the base of the seagrass stems.

Image 12: This image shows a seagrass restoration diver holding a makeshift bundle holder, held together by PVC pipe and zip ties. Image was from Hughes, Beheshti, Ward. 2021. "How to" of seagrass restoration. Seagrass Transplant and Restoration Team (START).

4. Then, you can use a 'bundle holder' to secure each bundle as depicted in Image 12 above, and secure them together with zip ties.
    - Creating a bundle holder is not required for every project.
    - If you are using a bundle holder it should be set up ahead of preparing the seagrass so that all you need to do is secure the bundle holder with zip ties.
    - It is possible to carry a bundle with your hands or place a bundle in your mesh bag. However, it may be less efficient than utilizing a bundle holder. If you decide to not use a bundle holder, substitute 'bundle holder' in Step-by-Step Instructions to Transplant with what best applies in your restoration.

5. Once the seagrass is zip-tied onto the bundle holder, the person who is supporting the transplanter will be in charge of it. They will assist the transplant diver.
6. Continue repeating processes 1-5 until all your seagrass from the cooler is prepared.

STAKING MARKERS

Prior to planting, you can create a map that shows where you will plant the seagrass. On this map, indicate where you will stake your markers. This is helpful for knowing the boundaries of larger plots such as an acre or more. For smaller individualized plots (e.g., less than 1 acre), it is ok to place markers on your plot while you transplant.

When the spot is chosen, a PVC pipe marker should be fixed into the sediment to mark your plot so you can come back to it while transplanting. The transplanter is in charge of this. We recommend that you create unique identifiers for each PVC pipe marker you use so you can easily revisit the site. Please see Monitoring and Datasheets on page 52 for more information.

- **IMPORTANT:** Do not place markers in areas that are heavily trafficked by boats.
- **NOTE:** Inserting the PVC pipe into the sediment can be done by hand, but may require a mallet to hammer it into harder sediment.
- For low-visibility restorations, tiny colorful flags or flagging tape tied around the PVC marker, can help with marking the plot. These tiny flags can easily go into the sediment without the use of tools. However, they should only be used as temporary markers during transplanting and removed immediately after to avoid contributing to marine debris.
- **IMPORTANT:** Remember any good restoration requires environmental stewardship and post-restoration cleanup. At the end of the project, it is up to you to clean up all PVC and artificial materials.

STEP-BY-STEP INSTRUCTIONS TO TRANSPLANT

At a minimum, you should be working in pairs to maximize efficiency and for safety. In each pair, one person is a transplanter and the other is a supporter. NOTE: On the other end of things, especially when harvesting and transplanting by foot, you want to minimize trampling and destruction of the benthos (e.g., crabs, mollusks, etc.) and will want to minimize teams and disturbance. To learn more on how you can minimize disturbance, check out the deer track method on page 49.

- The supporter handles the bundle of prepared seagrass shoots and helps the transplanter.
- The transplanter is doing the actual planting of the seagrass.

For more information about team size and team configurations, refer to Assembling a Team on page 26.

Follow these steps to plant seagrass:

1. Arrive at your transplant site with the following materials nearby:

- Your cooler with the prepared bundles of seagrass
- A garden trowel
- Several garden staples (varying from 25, 30, or 45 cm)
- Either a PVC marker or a tiny colorful flag to put into the sediment.[4]
- Underwater paper and writing utensils, transect tape, quadrat, and camera to make measurements and observations. (Note: Not all restorations will call for these items).

For more descriptions and information of the materials to plant on foot, please see Appendix E on page 62. If you are using SCUBA or snorkeling equipment, please see Appendix F on page 62 for information and descriptions on materials.

2. We urge you to plant at a spot at your site that was predetermined or that is easily accessible and has ideal light and clarity conditions. See Assessing Location Suitability on page 21 for more details on ideal conditions.
3. At the chosen plot area, the transplanter creates a single, shallow slit in the sediment (usually 5 cm deep) using their hand or a garden trowel. Within this slit is where the seagrass and garden staple will be planted.
4. Next, the supporter, who has the bundle of (e.g., 50) prepared seagrass, will remove (e.g., 5) seagrass from the bundle holder, and hand that seagrass to the transplanter. The amount of seagrass the supporter hands to the transplanter should be the amount that is affixed to each individual garden staple. (e.g. 5 seagrass per garden staple, etc.)
5. Then the transplanter should carefully use their hands to hold the shoots' rhizomes from the received bundle in place and position them under the bridge of the garden staple. This is shown in Image 13.
6. Position each piece of seagrass beneath the garden staple like how it is shown in Image 13. Repeat this process 5 times until you have 5 shoots under the garden staple's bridge.

4 Whether you decide to mark your project before transplanting or during transplanting depends on the size of your project.

- Planting in clusters of 2 or more seagrass per garden staple increases the chance of seagrass survival and is more efficient than planting one shoot per staple.

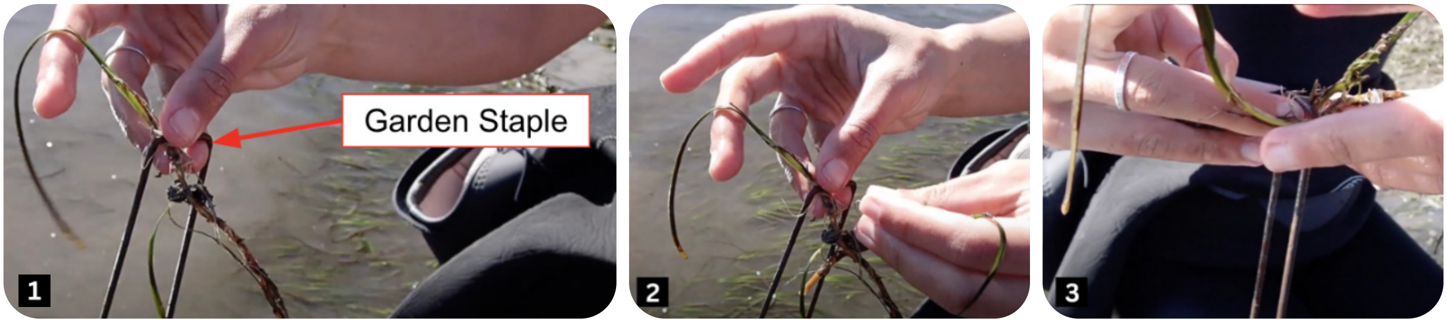


Image 13: A seagrass restoration team member demonstrates the correct way to position seagrass beneath a garden staple's bridge. 1. Shows a seagrass rhizome placed under the garden staple bridge, allowing its leaves to flow in the water. 2. Two seagrass sharing one garden staple with rhizomes under the bridge and leaves being able to flow in water. 3. Seagrass are positioned correctly and are ready to plant into the sediment. *Note: Do not tie the seagrass to the garden staple. The garden staple is what holds the seagrass to the sediment. All you need to do is place the shoots underneath the bridge of the garden staple as shown in the image above.* Image is taken from a video made by Dr. Kat Beheshti, Dr. Brent Hughes, and Dr. Melissa Ward in 2021.

7. Ensure that the seagrass stem and its leaves do not tangle under the bridge of the garden staple. This will harm the plant and it will die. An example of how seagrass leaves and stems flowing upward is shown in Image 15.

8. Next, arrange your 5 seagrass into a star formation. This is done by moving the seagrass rhizomes underneath the garden staple to make a star. Image 14 demonstrates what the star formation looks like when it is complete.
   - It is common for seagrass rhizomes to overlap underneath the garden staple bridge and that is okay.

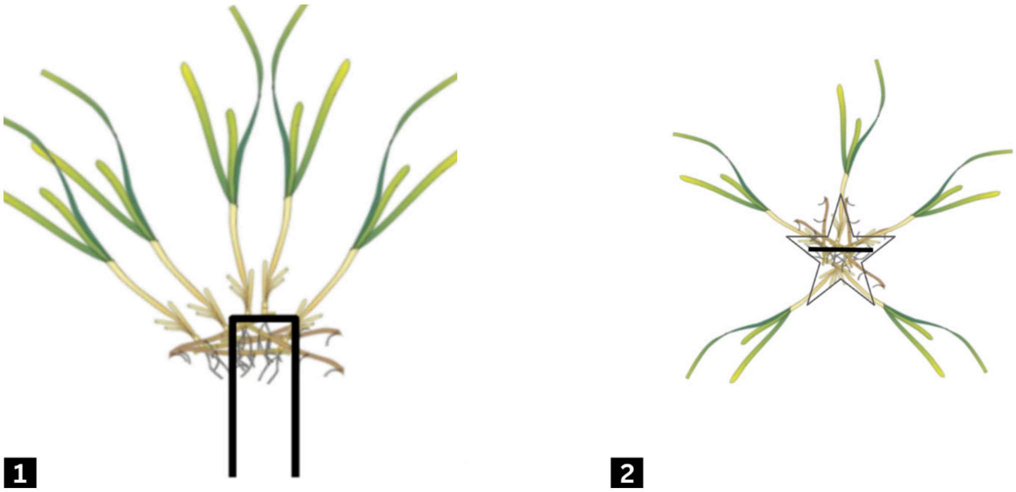


Image 14: The star formation used at Elkhorn Slough had 5 shoots per garden staple. The star formation is created by positioning the seagrasses' rhizomes underneath the garden staple bridge. Figure 1 shows a side view of the seagrass in a star formation. Figure 2 shows a top-down view of how the star formation should look like.

9. The transplanter carefully positions and secures the garden staple and shoots into the slit, ensuring that the rhizome and garden staple bridge are parallel to the sediment surface.
   - We recommend placing the cut end of the rhizome into the slit you made in the sediment, with a small portion of the meristem (where the seagrass leaf sprouts from the rhizome) exposed to the waterline. This allows it to receive nutrients for growth.

- Using a mallet to pound the garden staple into the sediment is useful if the sediment is too tough. Refer to Assessing Location Suitability for suitable seagrass sediment.

10. Fill the slit with sediment, shown in Image 15 below, to secure the seagrass in place with the garden staple. Ensure the seagrass leaves will be able to flow upward into the water.

Image 15: The seagrass slit has been filled with sediment and all seagrass leaves are flowing upwards after they have been successfully planted. Image is taken from a video made by Dr. Kat Beheshti, Dr. Brent Hughes, and Dr. Melissa Ward in 2021.

11. Our calculations, based on planting densities, revealed that transplanters should plant 5 seagrass shoots per garden staple and use 5 staples per 50 cm x 50 cm plot, as shown in Image 16 below. This corresponds to a density of 100 shoots per $1m^2$.

12. When the bundle is done, the supporter fetches another prepared bundle. When returning, make sure that the new slit made by the transplanter is at least 10 cm apart from other transplanted seagrass.

NOTE:
Although we have described the planting method in great detail, steps 3-12 above can occur quickly. To maximize efficiency, we recommend that you communicate with your team when you are nearing the end of your bundle, so a new bundle can be ready for you to plant.

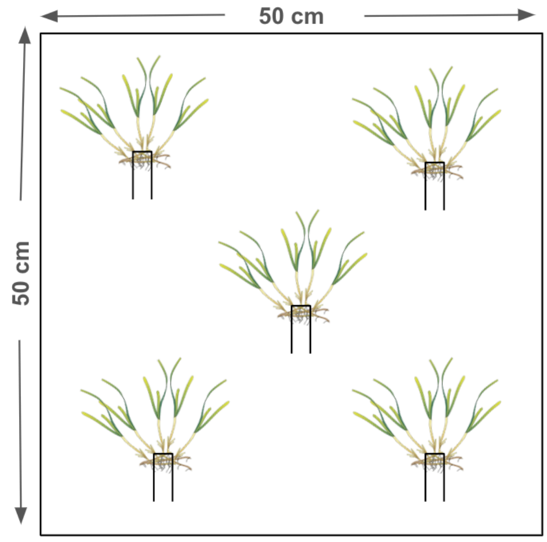


Image 16: Shown here is the seagrass transplant density for 50 cm. Each 50 cm should contain 25 shoots total and 5 seagrass per garden staple. *Note: The optimal plant density for a location may require you to plant in different formations, and this image is an example rendering for what worked at Elkhorn Slough.*

13. Record observations of the plot for future monitoring efforts with your underwater paper and water utensils.
    - For more details on what to monitor, please visit Monitoring and Datasheets on page 52.
    - If you require a camera for monitoring, and there is good visibility, at this step of the process would be a good time to take a photo. People on the boat can also take photos.

> **NOTE:**
> In projects that care more about whether or not seagrass survives and is less concerned about recording observations or research concerns, we can recommend that you skip over step 13.

Repeat steps 2-12 at your site until there is no more seagrass in the cooler and all plants are transplanted.

TRANSPLANTING BY FOOT

If you are on foot, transplanting instructions should only be followed if seagrass beds are reachable and accessible by walking to the site. If transplanting on foot is difficult, then you should consider SCUBA or snorkel. Transplanting on foot works best for shallow areas (< 1 meter) and areas that are accessible during low tides.

One advantage of transplanting on foot is that it is cheaper than renting SCUBA equipment and boats, which makes it possible for more people to take part in the transplanting process. To prevent trampling on seagrass beds, use the deer track method. The deer track method involves walking in the same path over time to create a track to shore or other areas. By having your team follow the deer track method, you will avoid trampling seagrass beds while doing restoration work.

TRANSPLANTING WITH SCUBA AND SNORKELING

If you are using SCUBA or snorkel, the transplanting instructions should only be followed in deeper waters.

A key difference between transplanting on foot versus utilizing boat-based SCUBA or snorkeling[5] is that boat location plays a role in positioning, plot boundaries, and safety. People on the boat need to be able to coordinate with those in the water for restoration efficiency and safety. Additionally, boat drivers can use GPS coordinates to pinpoint restoration areas and help guide people in the water to remain within the boundaries of the restoration area. Other key differences may arise in the following:

- Before using SCUBA diving equipment ensure all equipment is functioning properly. Test SCUBA gear beforehand, wear it correctly, and have someone in the boat ready to help in emergencies and take watch of the SCUBA divers.
- Using SCUBA requires that all divers are SCUBA certified. Additional SCUBA certification will depend on the country of restoration. For example, in the U.S., if the restoration is a university effort and uses SCUBA, ensure all divers are AAUS certified.

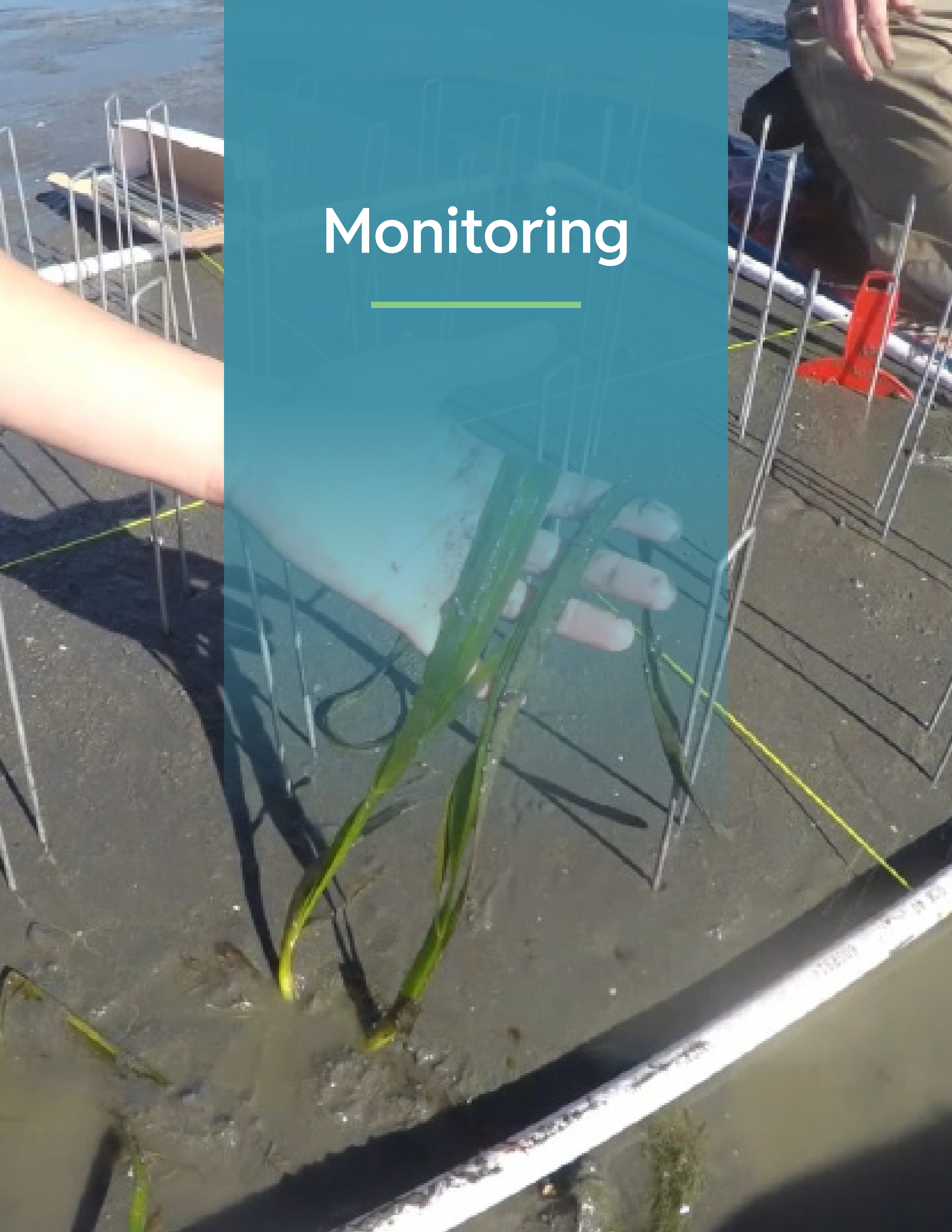
Image 17: Dr. Kat Beheshti is ready to plant two seagrass with a garden staple above a quadrat. The planting density calculated at a specific depth determines how many seagrass are planted per quadrat. For our project, we used five shoots per garden staple. Image was from a video made by Dr. Kat Beheshti, Dr. Brent Hughes, and Dr. Melissa Ward in 2021.

5 If SCUBA divers or snorkelers are not using a boat, they will need assistance from the shore to know when they are nearing plot boundaries and other forms of support.

When the water is deeper than 1.5 meters, it is better to transplant using SCUBA. This method is much faster, allowing transplanting of hundreds of shoots in just half an hour compared to snorkeling. If you choose to snorkel, you will follow the same transplanting process as SCUBA. However, it is critical that you stay close enough to the surface and the sediment to plant the seagrass, usually within arm's length, as this helps with your planting. In case of a substantial gap between the surface and sediment, plan for extra planting time or, if necessary, think about utilizing SCUBA.

NOTE:

- The time it takes to finish transplanting or harvesting varies depending on the strength of the current because it affects your team's effort to stay in place while planting. It usually takes a few minutes for a dive team to finish planting an entire seagrass bundle. We recommend monitoring the current, and rescheduling when the current is strong. Plant when currents are low, because it is more efficient and safer.
- While diving and snorkeling, it is best to kick your fins in the same direction as the tide to avoid stirring up sediment where you are planting.
- For SCUBA, we recommend keeping the support divers close to the boat and their transplant diver to assist in the transplant process when needed. This positioning keeps the seagrass moving from the boat to the support diver, then to the transplant diver, and finally into the sediment, ensuring smooth seagrass planting without long pauses for refills.



Monitoring

Monitoring and Datasheets

After planting your seagrass, it is crucial to monitor its progress over time to see if it is successful because not all projects succeed. Your "success" or "failure" depends on what you are trying to achieve with your project goals. For example, if you have decided to plant a certain amount of seagrass, success means it stays there for a set time, such as five years. Sometimes success is measured by how much the seagrass grows or other ecological indicators (e.g., changes in fish population).

In our project in Elkhorn Slough, we looked at many metrics of success/failure. The three primary metrics that most restorations should consider include:

- Did the planted seagrass persist?
- Did the transplanted seagrass expand or contract?
- Did transplanted seagrass maintain similar densities relative to control/reference plots?

To follow the progress of your restoration, it is important to monitor and check-in on your restoration plots. Seagrass can grow about 1 cm per day, depending on the specific site conditions. By following the instructions within this handbook, your transplanted seagrass will have a uniform height of 25 cm. So, within a few days or weeks, you should be able to see how well your restoration is progressing compared to the site you harvested the shoots from. We suggest waiting 3-6 months for certain measurements, like plot expansion rates, because expansions will not be noticeable before then. The simplest way to see whether your project was a success is whether the shoots you have transplanted have grown to have the same size as the donor bed and that planted densities are maintained or increasing.

Monitoring efforts should be tailored to your goals for the restoration and how you plan to manage it after transplanting. We recommend that all monitoring plans be made early on in the project, specifically during the planning of the project, since this will give time to help shape the objectives and goals of the project.

We suggest closely watching restored plots using your PVC pole markers during the initial two years after transplanting. Depending on your project size—whether it is many small plots or one big plot—it is crucial to check all plots to monitor the site's progress. Visit the site two weeks after planting to check for progress. Then, go monthly, every three months, and finally, annually. If you are not an expert, or your project is less focused about specific monitoring methods, we recommend that you monitor your project by trying to visit the site in-person on a semi-weekly or monthly basis to understand whether the seagrass was able to take root or not.

Measurements recorded during the monitoring process can tell you specific details on how your project is progressing. Important progressions in your project can be measured through changes such as shoot density counts and meadow expansion and retraction. In Elkhorn Slough, we inspected and monitored all 117 plots. We visited several individual plots at a time and then revisited the ones we had not checked before at another time. We would check on these plots on a weekly basis at first, then monthly for 4 months after the first month, then annually (during peak summer growing months- August or September for central California).

The measurements you decide to record and how you record them can vary for your project. Here are some examples below:

- **Seagrass Plot ID**: Each plot should have a distinct and specific identifier. Unique IDs are crucial for future monitoring and preventing confusion between unnamed plots.
  - At Elkhorn Slough, we utilized PVC pipes to mark the site and affixed dog-tags containing unique IDs for our individual plots onto these pipes. This made it easy for us to find plots and recognize their IDs.
- **Number of Shoots**: These data record the quantity of seagrass shoots within the plot ID.
- **Number of flowering shoots**: These data tallies the number of flowering seagrass shoots in the plot. Identifying flower shoots is easy as they resemble flowers found in a garden.
- **% of Algae Cover**: This estimates the amount of algae covering the plot. The percentage of algae cover can be a rough estimation.
- **Biomass**: Measure seagrass biomass by weighing harvested plant material, including both above-ground shoots and below-ground rhizomes.
- **Plot Area**: Calculated by measuring the plot's length by width using a transect tape or quadrat (a standard square measurement tool).
- **Canopy height**: Measures the height of the seagrass canopy from the sediment surface. An increase indicates healthy growth. Begin by identifying the longest leaf in the plot area and measure its length using a transect tape starting at the base of the leaf/node. Healthy seagrass in central California can grow up to 1cm a day!
- **Note section**: A space for adding plot-specific observations.
- If you are keen on **observing fish and invertebrate colonization** in the restored plots, we recommend using both trapping methods within the plots and collecting one shoot per plot for laboratory processing, specifically targeting small herbivore organisms.
  - At Elkhorn Slough, we utilized baited minnow traps and shrimp pots for this purpose.

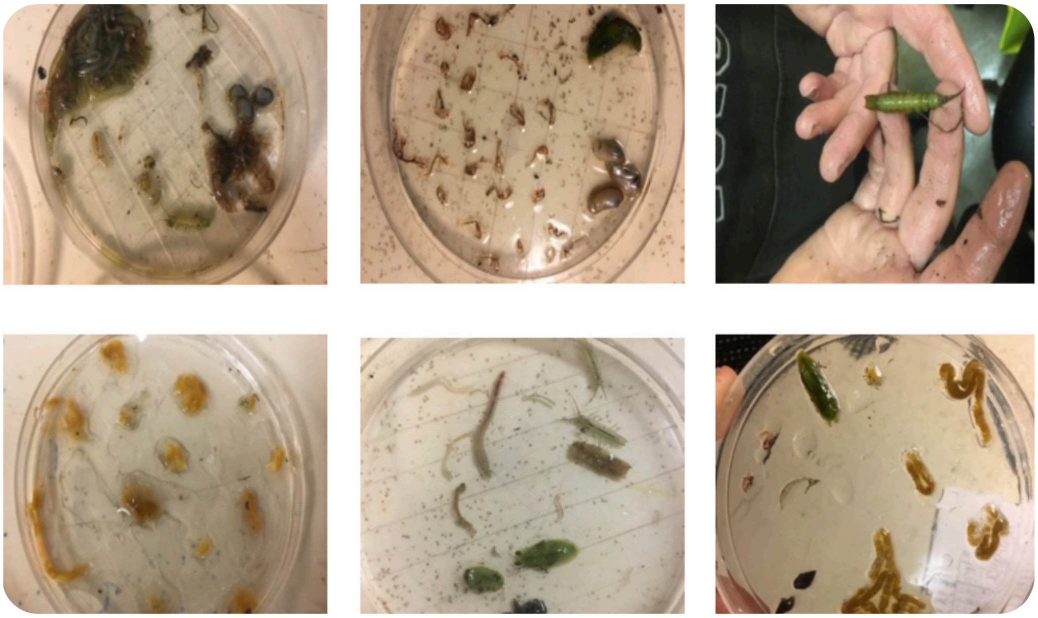


Image 18: The above photos are an assortment of mesograzers that were identified, sorted, sized, and weighed for our restoration in Elkhorn Slough — visually demonstrating the potential diversity and abundance of mesograzers in seagrass restoration plots. Images are taken from team members assisting in our Elkhorn Slough restoration in 2015-2018 (Beheshti et al. 2022).

FIELD DATASHEET

Creating a simple datasheet with columns to put in your measurements of seagrass is helpful for future monitoring efforts. If your project is more research oriented, we recommend customizing the datasheet to best help you with your research.

> **NOTE:**
> If your focus is mainly to plant seagrass and is less concerned about different measurements, a field datasheet might not be needed.

The purpose of the field datasheet is to collect and record information about the site, which includes important measurements about the natural seagrass or restored seagrass beds. A field datasheet is portable for field observations and adaptable to different project phases like pre-restoration assessments, the restoration, or post-restoration monitoring. If you are using a field datasheet, please make sure all measurements are recorded accurately.

Materials that can help with recording your datasheet:

- Underwater paper and writing utensils
- Tiny colorful flags
- Transect tape
- Camera
- PVC markers
- Quadrat

For more descriptions and information of the materials usually helpful to make recordings on your datasheet, please see Glossary of Terms on page 57.

A good field datasheet is usually designed to save space and efficiently collect data without unnecessary columns. It is best to print these sheets on underwater paper since they will be exposed to the elements during the restoration. Before using underwater paper, check if your printer supports it. Please see Appendix G on page 63 for an example of a field data sheet.

DATA MANAGEMENT

In projects focusing on seagrass research or closely monitoring its growth, managing data is critical. The project lead usually manages data, and it is checked twice for accuracy after initial entry to avoid mistakes. Metadata is entered in a separate sheet in the same Excel workbook for easier analysis later. Data entry should be compatible with preferred statistical software like R, Excel, SYSTAT, PRIMER, and JMP for analysis. Please refer to Appendix H on page 64 for an example of a data management sheet.

What's Next?

The results from a successful seagrass restoration supports various trophic levels, fostering a healthier and more resilient marine environment. Below are a few examples of how the benefits of your seagrass restoration can help other plants and animals living within your restored ecosystem.

OYSTER RESTORATION

- With oysters being susceptible to acidic environments, seagrasses can help regulate pH levels, which helps oyster survival.
  - In oyster-inhabited areas, oysters can actively aid in the growth of seagrasses by improving water quality which can facilitate a more favorable environment for seagrass growth.
  - When oyster beds and seagrass are growing nearby, it can help to protect the shoreline from rising water levels.

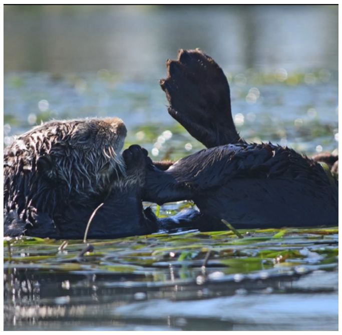
Photo by @bugphai via Freepik.

SEA TURTLES AND MANATEE CONSERVATION

- Sea turtles and manatees can benefit from seagrass restoration because seagrass is a major part of their diets (Stokes et al., 2019; Lefebvre et al., 2017). Restoring, protecting, and conserving seagrass can have a positive impact on their health and survival.

FISHERY ENHANCEMENT AND BUILDING HABITAT FOR SPECIES

- Seagrass beds serve as critical nurseries and habitats for many fish species. It is possible for your restoration project to increase fish populations (see Beheshti et al. 2022), and this can benefit both commercial and recreational fisheries.
- Seagrass meadows also provide habitat for various invertebrates such as crabs, shrimp, and scallops (Orth et. al, 2020).
  - Increased abundance of invertebrates like crabs also helps fill the diets of other important ecosystem species such as sea otters (Hughes et al., 2013)



SEAGRASS RESTORATION AND SEA OTTERS

- Seagrass restoration and sea otter populations have a mutually beneficial relationship. Sea otters play a favorable ecological role in seagrass expansion by preying on species that eat seagrass, while estuaries with a healthy seagrass population provide an ideal habitat for sea otters. A healthy sea otter population not only helps restore seagrass, but also generates a trophic cascade, enhancing coastal wetland plant biomass and stabilizing marsh edges. These effects reduce coastal erosion and contribute to the overall health of the broader ecosystem. (Hughes et al., 2024).

Additional Resources

Image taken by Abbey Dias

Glossary of Terms

Camera: While not explicitly recommended, this is helpful for taking pictures of the plot and visual growth of the seagrass during monitoring. If you are using SCUBA, we recommend using underwater cameras.

Cooler: Coolers contain harvested seagrass. You can use every cooler as a seagrass container by filling it with seawater from the donor site to prepare for the transplant site. The seawater inside the cooler should be enough to submerge the seagrass. Harvested seagrass survives comfortably in the cooler for 24 hours.

Datasheets printed on underwater paper and writing utensils: These items will assist with data entry and measurement recording during the restoration and monitoring. It is a good idea to use underwater paper since regular paper might get wet while you are working in natural surroundings during the restoration. Creating a simple datasheet on underwater paper with columns to put in your measurements of seagrass is helpful for future monitoring efforts. If your project is more research oriented, we recommend customizing the datasheet to best help you with your research.

- Before using underwater paper, check if your printer supports it.

Documentation such as permits and waivers: This paperwork allows the seagrass restoration and its personnel to have proper legal approval to proceed. Please make sure to have this with you while conducting your restoration.

- For the Elkhorn Slough Restoration, our permit was under a Scientific Collection Permit with the California Department of Fish and Wildlife. For more information on the Scientific Collection Permit, please see Further Resources on page 66.

First Aid Kit: This contains typical medical supplies like bandages, antiseptic ointments, and disposable gloves, among other important items.

- If resources are available, it is recommended to have an **AED** handy with your first aid kit. An AED kit is a defibrillator, and it assists with restarting a normal heart rhythm in case of a medical emergency.
- If you are doing a SCUBA seagrass restoration, we recommend that everyone onboard the boat wears **life jackets**.

Garden staples: These items secure the seagrass to the sediment so they will not float away from the site. Most garden staple sizes work for a restoration. Determine the size of the garden staple you need by the sediment type and the current speeds of the site.

- We used 25 cm, 30 cm and 45 cm garden staples for the majority of sites we planted in Elkhorn Slough. Garden staples of 30 cm and 45 cm are ideal for areas with a potential mix of mud, sand, and even bedrock layers. The 45 cm garden staples, in particular, offer enhanced anchorage, making them especially effective in areas involving high current speeds.

Garden trowel: This tool will assist you with the transplanting of seagrass. Garden trowels are used to create slits in the sediment to put the seagrass and garden staples into it.

GPS: This tool aids seagrass restoration by mapping, navigating, collecting data, monitoring, documenting, and coordinating efforts. If you are doing a restoration using SCUBA, it is helpful to have your boat driver be in charge of this tool. With a GPS, boat drivers are able to easily alert everyone when they have arrived at the site and are able to distinguish the borders of the restoration.

Mesh bags: These are used for carrying harvested seagrass from the donor bed to the cooler and from the cooler to the transplant site. You can place as many seagrass shoots as will comfortably fit in the mesh bag. Mesh bags are useful because they let you shake off extra sediment that you do not want to carry around.

PVC for marking plot location: A PVC pipe helps with marking the correct plot location, and it is useful for recording observations within the plot and future monitoring efforts. The PVC pipe should not be sticking out of the sediment too much where it would obstruct traffic to that area, nor should the PVC pipe be in the ground so much that it is hard to notice it later on during monitoring. Please use your best judgment on how deep the PVC marker should go. Also, make sure to put a mark or something unique on the PVC to recognize the correct one later. You can use numbers on the PVC for plot identification, colorful flagging tape, or other distinctive items as identifiers.

- It is useful to include a **mallet** to hammer in the PVC pipe, just in case you come across harder sediment. At Elkhorn Slough, most of the time we were able to simply stick in the PVC pipe into the sediment, and only a handful of times we had to rely on a mallet.

SCUBA gear or **waders**: Waders and SCUBA gear are generally recommended for a restoration that involves being in the water. Please wear the appropriate clothing and gear at the site that best assist you in performing your job.

- If you are doing a SCUBA seagrass restoration, please ensure that you have **extra oxygen** on the boat. It is a safety precaution and is always good to have nearby. Make sure that everyone has dive computers, and that spotters are tracking divetime.

Shears/scissors: These tools trim long seagrass into shorter ones and assists with transporting seagrass between sites. Ahead of any trimming, it is important to have your scissors/shears sterilized. Sterilizing your scissors/shears will prevent fungal pathogens being introduced to the site. Importantly, scissors or shears are used to cut above the meristem during harvesting. Cutting above the meristem signals the seagrass to "regrow," helping it adapt swiftly to its new location and make the seagrass smaller and easier to handle by your team planting it.

Site selection instruments: During the site selection, instruments such as **turbidity readers** and **light readers** are helpful for you to know what the site conditions are and whether or not that spot is good for seagrass to grow there. Using these tools during restoration helps collect more measurements at the site.

Tiny colorful flags: Using small, colorful flags can help mark plots during SCUBA restorations in low-visibility conditions, but they should only be used as temporary markers during transplanting and removed immediately after to avoid contributing to marine debris.

Transect tape: Transect tape is used for precise measurements, spatial planning, and effective monitoring in seagrass restorations. These are generally helpful for small individualized plots for your restoration. If you have a large plot for your restoration, then this item may not be relevant.

- If your project focuses on smaller, individual plots (like 1-meter plots), we suggest using a quadrat to help with monitoring. Quadrats, small PVC frames that can range in size from 25 cm x 25 cm to 1 m x 1m (smaller quadrats are useful in seagrass areas with high densities, ex. 1000s of shoots per m^2) help standardize plot sizes for seagrass transplanting. They are used to measure plant distribution. To prevent it from floating away, we advise drilling holes into the PVC pipe of your quadrat.

Zip ties or electrical tape: These are handy for assembling seagrass bundles from the cooler into more organized bundles to hand off to transplanters.

Appendix A: Permitting

Ahead of any site selection make sure that you get permits and the right documentation. Without permits and proper documentation, you could face legal consequences. In states like California, the permitting process can be expensive and time consuming, while in other states there may not even be a permitting process. Check to see what rules and regulations apply in your area before transplanting seagrass and follow those rules.

For our Elkhorn Slough restoration, we applied for and received a Scientific Collection Permit through the California Department of Fish and Wildlife (CDFW). This permit is for restorations affecting an area of fewer than five hectares. If your project is in California and will impact more than 5 hectares, you will need an environmental review, which can take 6 to 12 months. This type of permit requires hiring an expert and could cost up to $60,000 - $100,000 in total.

Depending on where the restoration is occurring, biodegradable planting materials may be required. For places like San Francisco Bay, permitting is necessary, including the use of biodegradable materials. You will have CDFW as well as Bay Conservation and Development Commission (BCDC) and Army Corps of Engineers (ACOE) permit approvals. You are also required to monitor donor beds to be sure you do not have negative impacts from our collections. These may not all apply depending on where the restoration is happening, but check with local environmental permitting agencies to be sure you have permissions you need. Also, you have to be sure you have landowner permission. This often requires an encroachment permit. Encroachment permits may not apply in other locations, but in places where you can own the deep intertidal/shallow subtidal, it is always good to double check.

For more information about the California Department of Fish and Wildlife and Scientific Collection Permits, see Further Resources on page 66.

Please take into account that obtaining a permit is a lengthy process, often taking at least 6 months to obtain. However, while waiting for those permits and documentation, it is a great time to knock out any project planning or logistics.

Appendix B: Recommended List of Materials for all Projects

- Turbidity Reader
- Light Reader
- SCUBA Gear
- Mesh Bags
- Garden Trowel
- Garden Staples
- Cooler
- Scissors/Shears
- Zip Ties
- Electrical Tape
- PVC for Marking Plot Location
- Mallet
- Tiny Colorful Flags
- Datasheets on Underwater Paper and Writing Utensils
- Transect Tape
- Quadrat (50 cm x 50 cm). Remember 50 x 50 cm = 0.25 m^2.
- First Aid Kit
- Life Jackets
- GPS
- Camera

> **Note:**
> This list will vary depending on your project goals.

Appendix C: Example Budget

Item	Quantity	Expected Price	Expense Category
Personnel salary	Varies	**Experts:** ~$20-$150/hr **Volunteers:** Free or set per diem rates (varies)	Labor
Boat related expenses	Varies	~ $2,000-$7,000 per day depending on size of vessel and project location.	Transportation
Travel to site	Per team member	Round trip gallons used x price per gallon, or use standard mileage reimbursement rates if it applies to your area.	Transportation
Turbidity Meters[6]	1	~$70 or more per item	Field work
Light Reader	2	~$70 or more per item	Field work
SCUBA Gear	Per diver needed	Varies	Field work / Safety
Mesh Bags	Per diver needed	~$150 for several bags	Field work
Garden Trowel	Per diver needed	~$7-$15 per item	Field Work
Garden Staples	Varies per project size	~$7-$15 for several staples (price varies per size)	Field Work
Cooler	Varies per project size	~$30 or more per item	Field Work
Scissors/ Shears	Varies per project size	~$5-$10 per item	Field Work
Zip ties or electrical tape	Varies per project size	~$5-$10 per item	Field Work
PVC for marking plot location	Varies per project size	~85¢ /ft per item	Monitoring /Field Work

6 Light readers can offer similar readings as turbidity meters.

Item	Quantity	Expected Price	Expense Category
Mallet	1 per boat or team	~$5-$20 per item	Monitoring / Field Work
Tiny colorful flags	Varies per project size	~$5-$10 per pack	Monitoring / Field Work
Datasheets on underwater paper and writing utensils[7]	Varies per project size and goals	~$30-$100 per pack of underwater paper ~$10-$30 per pack of all-weather writing utensils	Monitoring / Field Work
Transect tape	2	~$30-$100 per item	Monitoring / Field Work
Quadrat	Varies per project size and goals	~85¢ /ft per item	Monitoring / Field Work
First Aid Kit	1	~$30-$100	Safety
AED	1	~$100 or more	Safety
Life Jackets	Varies per project size	~$15 or more per item	Safety
GPS	1	~$100 or more	Navigation / Fieldwork
Camera	Varies per project size and goals	Varies on quality of camera you use	Monitoring / Field Work
Total #	**Varies per project**	**Varies per project**	

Note:
This sample budget is not representative of all project pricing. Figure out how many things you need and how much they will cost by considering the quality of materials you want, how big your team is, and the size of your project site.

Appendix D: List of Materials Needed for a Site Survey

- Transect tape measurers
- Underwater paper and writing utensils
- Appropriate footwear or SCUBA gear
- GPS
- Camera, if your project uses it
- PVC markers
- Quadrat

7 This price may vary depending whether you use writing utensils from your personal supply.

Appendix E: List of Materials needed when Transplanting on Foot

- Proper footwear
- Permits and waivers
- Your cooler with harvested seagrass
- Zip ties
- Electrical tape
- Scissors
- Garden trowel or a small gardening tool
- Garden staples
- Plot marker (usually made out of PVC pipe) or tiny colorful flags
- Mallet in case you encounter unexpectedly hard sediment at the transplanting site.
- Monitoring equipment such as underwater paper and utensils, and a camera if your project uses it.
    - If your project focuses on smaller, individual plots (like 50 cm x 50 cm plots), we suggest using a **quadrat** to help with monitoring.
- First AID Kit
- GPS

Appendix F: List of Materials needed when Transplanting on SCUBA and Snorkeling

- Permits and waivers
- A boat
- GPS
- Life jackets for the crew on the boat
- SCUBA materials
- Emergency O_2 for the divers
- First AID
- AED
- Your cooler with harvested seagrass
- Zip ties
- Electrical tape
- Scissors
- Garden trowel or a small gardening tool
- Garden staples
- Plot marker (usually made out of PVC pipe)
- Tiny colorful flags
- A mallet in case you encounter unexpectedly hard sediment at the transplanting site.
- Monitoring equipment such as underwater paper and utensils, and a camera if your project uses it.
- If your project focuses on smaller, individual plots (like 1-meter plots), we suggest using a **quadrat** to help with monitoring.

Appendix G: Example of Field Datasheet

Name			
Date		Site	

Meta Data			
Hight Tide (HT):		Low Tide (LT):	
HT_Time:		LT_Time:	
Weather Conditions:			

Plot_id	#_Shoots	#_Flowering Shoots	%_Cover_ Algae	Plot_area (Cm)	Canopy_Height (Max)	Notes
Ex. A_1_R16	25	6	5	257x455	103	algae accumulated on PVC post marking plot area

Field Notes

Plot_ID written as STRATA_PLOT#_RESTORATION YEAR---> A_1_R16 reads Strata A, Plot#1, Restoration 2016 Saw juvenile rockfish in B_2_R16, large Aplysia california in A_8_R16 and C_7_R16

Appendix H: Example of Metadata Sheet

Meta Data			
Field Date:		Data Entry Date:	
Name(s) of field crew:			
Name(s) of data entry personell:			
Excel File Name:			
Corresponding Excel Sheet Name:			
Hight Tide (HT):		Low Tide (LT):	
HT_Time:		LT_Time:	
Weather Conditions:			

Field Notes

Date	Initials	Sheet_Name	Note
1/28/18	KMB	R2016Monitoring_Data_01082018	field data entered up to field day 1/10/2018
	KMB	R2016Monitoring_Data_01082018	all data entered, need to QA/QC

Date	Strata	Plot	Restoration_ year	#_Shoots	#_Flowering shoots	%_cov-er_algae	Plot_ area_x_cm	Plot_area _y_cm	max_cano-py_height	Notes
1/1/18	A	1	2016	25	6	5	257	455	103	algae accumulated on PVC post marking plot area

Further Resources

WATER QUALITY:

To look up the water quality in your area, try the links below:

- Environmental Protection Agency National Aquatic Resource Surveys
  - https://www.epa.gov/national-aquatic-resource-surveys/data-national-aquatic-res ource-surveys
- USGS Water Quality Data
  - https://www.usgs.gov/mission-areas/water-resources/data#USGS
- National Estuarine Research Reserve System Centralized Data Management Office
  - https://cdmo.baruch.sc.edu/
- California Water Boards State Water Resources Control Board
  - https://www.waterboards.ca.gov/resources/data_databases/

PERMITTING & GUIDELINES:

To learn about the permitting/certifications required for your field site try the links below.

- AAUS Scientific Diving Certification/Institutions
  - https://www.aaus.org/AAUS
- California Department of Fish and Wildlife: https://wildlife.ca.gov/
- California Department of Fish and Wildlife, Scientific Collection Permit: https://wildlife.ca.gov/Licensing/Scientific-Collecting
- NOAA Fisheries California Seagrass Mitigation Policy and Implementing Guidelines
  - https://www.fisheries.noaa.gov/west-coast/habitat-conservation/seagrass-west-co ast
- National Marine Sanctuary Permitting
  - https://sanctuaries.noaa.gov/management/permits/welcome.html
- U.S. Fish & Wildlife Permitting
  - https://www.fws.gov/service/permits

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