Culebra Seagrass Monitoring Work Plan

Developing a seagrass monitoring program to evaluate changes in LBSP responses in Culebra, Puerto Rico

1. Introduction and Background

Globally, nearly a billion people live within 100 km of a coral reef ecosystem (Sing Wong et al. 2022) and potentially benefit from ecological services provided by seagrasses. Seagrasses are particularly vulnerable to human disturbances because they usually occupy sheltered, shallow nearshore waters proximal to coastal discharge and drainage endpoints. Sediment impacts (i.e., the combination of sedimentation and turbidity) on seagrass communities include light reduction, smothering, and changes in the physicochemical condition of the plant's root microbiome; which together can reduce the depth range and areal extent of the meadow, decrease shoot density, and ultimately alter species composition and community function (Duarte 1987, Dennison 1997, Saunders et al. 2017). Concomitantly, the excessive growth of epiphytes, macroalgae, and phytoplankton under high nutrient loads decreases seagrass growth and survival (Lee, Park & Kim 2007; Schmidt et al. 2012).

This monitoring work plan is a key component of Culebra's LBSP Ridge to Reef Monitoring Program aimed at providing standardized guidelines and methods to monitor changes in land-based pollutant loads, nearshore land-based pollutant exposure, and seagrass habitat responses across the island. These monitoring activities are spatially and temporally coordinated and represent the basis of Culebra's Integrated LBSP Monitoring and Evaluation Framework to successfully evaluate progress toward achieving NOAA's LBSP management goals and outcomes on Culebra.

2. Monitoring Objectives

This work plan addresses biological response endpoint monitoring; specifically, seagrass monitoring to evaluate proximal effects of LBSP management actions to address increased nutrients and terrigenous sediment transport to Ensenada Honda and associated nearshore waters of Culebra. Seagrass is viewed as a sentinel indicator of the effects of management actions because they are located more closely to the source of pollution than the coral reef track which is ultimately the key biological response endpoint of protection. Therefore, this monitoring is aligned with the following NOAA LBSP management goals, outcomes, and evaluation questions:

Management Goal:
- Management Goal: By 2035, improvements to Culebra's nearshore seagrass community condition.

Management Outcomes:
- Improve nearshore seagrass habitat condition

Evaluation Question:
- Have the seagrass habitat conditions improved?

This seagrass monitoring work plan was designed to:
1. Develop status and trends baseline assessments to track changes in the condition of seagrass communities in the nearshore waters of Culebra.
2. Provide the basis to assess the performance of upland restoration activities to reduce LBSP impacts on nearshore habitats of Culebra.
3. Conduct outreach activities to inform and to engage both local community, federal, and Puerto Rican government officials in ongoing natural resource management, restoration, and conservation efforts on Culebra.

3. Monitoring Location and Frequency

In 2014, NOAA Restoration Center and Coral Reef Conservation Program conducted a baseline assessment to provide estimates of pre-restoration conditions of the seagrass communities in Ensenada Honda and associated nearshore waters. Successive post-restoration status and trends monitoring was completed in 2022. The following sections briefly describe the methods and procedures implemented to collect those data.

Monitoring Locations

The seagrass monitoring shall occur co-located with the fixed nearshore water quality and sediment trap monitoring stations identified in Figure 1 and Table 1. These locations were selected based on the following criteria:

1. Watershed hydrology and coastal hydrodynamics as well as the level of existing level LBSP exposure and anticipated changes to LBSP exposure due to management actions (Appendix A: Identifying Priority Fixed-Site Monitoring Locations).
2. Nine pre-restoration locations in Ensenada Honda sampled in 2014 for baseline assessment of seagrass community and water quality.
3. Locations of particular community interest and cultural significance—Tamarindo beach in the Canal Luis Peňa Natural Reserve.

Figure 1. Nearshore seagrass transects monitoring stations on Culebra.

In Figure 1, LBSP Restoration sites (blue) are locations where LBSP BMPs have been implemented and are therefore locations where LBSP management is occurring. LBSP Control sites (yellow, red, and green) are locations where there is presently no LBSP management occurring. These control sites were selected to represent a range of LBSP impairment, including Control (yellow) which have no known direct discharge of LBSP but are representative of the range of external factors (currents, wave and wind energy) that may be encountered at the treatment sites; a Negative Reference site (red) of significant LBSP impairment, as well as a Positive Reference site (green) of low LBSP impairment. A citizen science site was also selected for its cultural and community significance.

Tracking changes in seagrass community composition at both impaired and restored watershed points will contribute information about whether seagrass biological responses follow changes in the levels of exposure to LBSP impacts through time in the presence and implementation of installed LBSP BMPs. Monitoring of exposure and response indicators at nearshore fixed stations that represent. LBSP management performance in the nearshore will be evaluated by comparing measures of indicators at control/reference sites against LBSP impacted and restored sites. In general, measures of indicators from restored sites that show progress toward control/reference conditions will be indicative of improvements.

Table 1. Nearshore seagrass transects monitoring locations and survey efforts in 2014 and 2022.

Monitoring station	**LBSP Treatment Group**	**2014**	**2022**	**Latitude**	**Longitude**
Aeropuerto	Negative Reference		x	18.30992198	-65.29986802
Fulladosa Bay	LBSP Restoration	x	x	18.29583703	-65.28758702
Fulladosa Point	LBSP Control	x	x	18.29693296	-65.28617199
Fulladosa Ramp	LBSP Restoration	x	x	18.29949799	-65.28839897
Casa Azul	LBSP Control	x	x	18.30045604	-65.29005901
Cementerio	LBSP Control		x	18.30725703	-65.28564602
Villa Terruño	LBSP Restoration	x		18.30132	-65.29364
Coronel	LBSP Restoration	x	x	18.30910197	-65.28999598
Cabra	LBSP Restoration	x	x	18.30611902	-65.28126203
Little Cabra	LBSP Control	x	x	18.30234298	-65.28058897
Mosquito	Positive Reference	x	x	18.29204799	-65.26311697
Tamarindo	Positive Reference	x		18.31776	-65.31768
Puerto Manglar Treatment	LBSP Restoration		x	18.30603202	-65.25161197
Puerto Manglar Reference	Positive Reference		x	18.30523599	-65.25083799
Puerto Manglar Control	LBSP Control		x	18.30557001	-65.25825497

Monitoring Frequency

Pre- and post-restoration surveys were completed in 2014 and 2022 respectively. Subsequent status and trends monitoring should be conducted every three to five years.

4. Monitoring Parameters

Physical and biological indicators provide a measurable proxy for assessing changes in stressors, exposures, and responses over time to evaluate management success. Seagrass responses to natural and anthropogenic disturbances can be quantified as changes in habitat areal extent, benthic cover, and density. Additionally, declines in water quality and clarity, as well nutrient enrichment can be measured by the proliferation of both epiphytic and drift algae which in turn affect seagrass productivity and survival. Based on input from subject matter experts, the top response indicators selected for this monitoring work plan were: (1) indicators of seagrass community condition, and (2) logistically feasible; and are outlined below:

- Indicators of seagrass community condition:
    - Benthic cover—a measure of relative abundance of the principal bottom-dwelling community components.
    - Shoot density—the number of seagrass shoots per unit area (m^2) to inform small scale and species changes within the larger seagrass habitat complex.
    - Epiphyte load.
    - Deep edge of bed.

Changes in seagrass responses will be evaluated through comparisons of site-specific measurements of indicators before and after the implementation of BMPs. If measures of seagrass indicators at monitoring sites demonstrate positive change in restored areas that are commensurate with changes in indicators of water quality and sediment threats, this would indicate that pollutant exposure is improving as a result of management actions.

5. Data Collection Methods

In 2014, a seagrass pre-restoration baseline assessment for LBSP impacts was conducted at nine nearshore monitoring sites in Bahia Honda and one site at Tamarindo beach (Table 1). In 2022 post-restoration seagrass assessments were completed at eight Bahia Honda sites previously surveyed in 2014, plus three additional sites in Puerto de Manglar and one site adjacent to the airport. To the extent that logistics permitted, post-restoration surveys replicated the original 2014 seagrass sampling protocol effort.

The following sections briefly describe methods and procedures implemented to conduct the pre- and post-restoration seagrass monitoring effort to evaluate changes in these seagrass communities over time.

Seagrass Sampling

Pre-monitoring equipment checklists, datasheets, and marine floral identification guides are provided with links at the end of this document. Three replicate 30 meter transects were set up at each site oriented perpendicular to shoreline and extending towards open water. A 0.25 m^2 PVC sampling quadrat (50 cm × 50 cm) divided into 25 grid units (10 cm × 10 cm each) (Figure 2) was used to estimate attributes of the seagrass community within each of 30 quadrats sampled contiguously—one at each meter mark—along the 30 m transect. Within each 0.25 m^2 quadrat seagrass community attributes were recorded implementing visually estimated Braun Blanquet (1965) index scores (Table 2). Prior to the initiation of data collection, the divers checked and calibrated their mutual Braun-Blanquet index scores for each species of seagrass present in the quadrat.

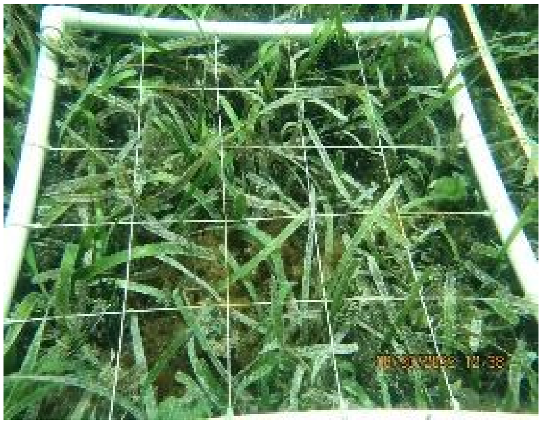


Figure 2. Illustration of the 0.25 m^2 PVC sampling quadrat (50 cm × 50 cm) divided into 25 units.

Table 2. Braun Blanquet Index scores and associated percent cover ranges.

Braun Blanquet Index Score	**Estimated % Cover**
0	not present
0.1	single or rare
0.5	very few
1	<5%
2	5–25%
3	>25 –50%
4	>50–75%
5	>75–100%

Attributes recorded included:

1. Total seagrass cover by species (i.e., *Thalassia testudinum*, *Syringodium filiforme*, *Halodule wrightii*, and *Halophila stipulacea*). *Halophila* should not be considered in the total seagrass cover score, but should be recorded as an individual seagrass species.
2. Total cover of macroalgae, calcareous algae, sponge, corals, and sediment.
3. Epiphytic load index.
4. Short shoot densities. Collected within a single randomized 100 cm^2 (10 cm × 10 cm) grid box within each quadrat along the 30 m transect.

Establishing the Transects:

1. Navigate to site
    a. Replicate transect begin (shoreward) and end (seaward) GPS coordinates are provided in Table 3 at the end of this document.
2. Establish a landward edge of transects:
    a. All transects will begin at the shoreline and run seaward perpendicular to shore. Record the latitude and longitude coordinates for the shoreward end of the transect.
    b. The shoreward edge should reach the shallowest area a snorkeler can effectively do the survey. This edge might not reach the shoreline in some sites, depending on the nearshore underwater topography.
3. Establish the 30 m end of transect
    a. Navigate (or swim) perpendicular from beginning of transect for 30 m.
    b. Use a 100 m measuring tape to establish the 30 m end of the transect.
    c. Mark the seaward end with ~½ inch rebar driven into the seabed.
    d. Record the latitude and longitude GPS coordinates for the seaward end of the transect. Note: At sites where there is enough depth (>3 m) and no hazards to install sediment traps at the seaward end of the transect, installing a marker rebar is not necessary since the sediment trap will mark the end of the transect.
4. Establish the edge of seagrass bed location
    a. Swim or navigate to the seaward end of seagrass bed and drop a weighted buoy.

    b. Record the latitude and longitude GPS coordinates for the seaward end of the seagrass bed.
5. Establish replicate 30 m transects
    a. Once the central or base transect is established—this is Transect 2 see Table 3—replicate parallel transects should be established at a 5 m distance on either side of the base transect.
    b. Establish landward and seaward ends of the replicate transects by measuring 5 m perpendicular on both sides of the base transect and temporarily marking beginning and ends of transects. It should not be necessary to permanently benchmark the replicate transects.

Seagrass Monitoring:

1. Use 100 m measuring tape to define the transect, aligning the 1-meter mark at the beginning of the transect.
2. At each sampling point along the transect (i.e., each meter marking), lay down the 0.25 m^2 quadrat immediately adjacent to the transect line on the right side (when looking seaward) of the transect.
3. Before initiating the data collection, the divers review and calibrate their estimates of cover using the Braun- Blanquet index scores.
4. Estimate and record the percent cover of total and species-specific seagrass implementing the Braun-Blanquet index scores.
    a. *Thalassia testudinum*, *Syringodium filiforme*, *Halodule wrightii*, and *Halophila stipulacea* are the most commonly encountered seagrass species.
    b. Note: *Halophila* should not be considered in the total seagrass cover score, but should be recorded as an individual seagrass species.
5. Record index score values for total macroalgae (drift and attached), epiphytes, crustose coralline algae, sponges, coral, and sediment.
6. At each sampling point along the transect line record short shoot density (SSD) for the dominant seagrass species (i.e., the species with the highest BB score) within a single randomly selected 10 cm × 10 cm grid box within the quadrat.
7. Repeat steps 1–6 for all the 30 quadrats (sampling units) along the 30 m transect.
8. Repeat steps 1–7 for left and right replicate transects at each site.
9. *For base transect only: Divide the distance between the end of the 30 m transect and the seaward edge of the bed by 4. Use that distance as a reference to complete four, progressively seaward, 0.25 m^2 quadrat surveys between seaward end of transect and edge of seagrass bed. Record the Braun-Blanquet scores for the cover attributes and shoot densities at each location.

Level of Effort

The sampling effort should take approximately 6 days in the field including boat travel to and from mainland Puerto Rico. Days 1 and 6 will include travel to and from Culebra, accommodation check-ins, boat and gear checks, logistics setup, and sampling at one site within Ensenada Honda. On day 2 divers will reconvene to address logistical and methodological inquiries and challenges, inter-observer variability, and sampling will take place at two sites. On days 3 through 5 divers will survey three sites per day with one day explicitly dedicated to sampling in Puerto Manglar which is the most weather dependent locale.

Table 3. Geolocation of the nearshore seagrass replicate monitoring transects surveyed in 2022. From the shoreline looking seaward Transect 2 is central or base transect. Transects 1 and 3 run parallel, 5 m to the right and left of Transect 2, respectively.

Site ID	**Transect 1 Start Latitude**	**Transect 1 Start Longitude**	**Transect 1 End Latitude**	**Transect 1 End Longitude**	**Transect 2 Start Latitude**	**Transect 2 start Longitude**	**Transect 2 End Latitude**	**Transect 2 End Longitude**	**Transect 3 Start Latitude**	**Transect 3 Start Longitude**	**Transect 3 End Latitude**	**Transect 3 End Longitude**
Aeropuerto	18.30993	-65.2999	18.30965	-65.30003	18.30992	-65.29987	18.30964	-65.29994	18.30993	-65.29974	18.30965	-65.29981
Cabra	18.30611	-65.28132	18.30594	-65.28146	18.30612	-65.28126	18.30594	-65.28138	18.30612	-65.28122	18.30588	-65.28117
Casa Azul	18.30046	-65.29	18.30066	-65.28985	18.30046	-65.29006	18.30071	-65.28989	18.30049	-65.29014	18.30071	-65.29002
Cementerio	18.30726	-65.28574	18.30704	-65.28552	18.30726	-65.28565	18.30708	-65.28544	18.30731	-65.28559	18.30716	-65.28538
Coronel	18.30917	-65.29	18.309	-65.29024	18.3091	-65.29	18.30895	-65.29021	18.30908	-65.28997	18.30887	-65.29018
Fulladosa Bay	18.2958	-65.28761	18.29557	-65.28745	18.29584	-65.28759	18.29571	-65.28735	18.29586	-65.2876	18.29577	-65.28731
Fulladosa Point	18.29689	-65.28619	18.29681	-65.2859	18.29693	-65.28617	18.29686	-65.28585	18.29699	-65.28618	18.29694	-65.28589
Fulladosa Ramp	18.29947	-65.28836	18.29958	-65.28814	18.2995	-65.2884	18.29968	-65.2882	18.2995	-65.28846	18.29971	-65.28828
Little Cabra	18.30235	-65.28063	18.30207	-65.2806	18.30234	-65.28059	18.30209	-65.28049	18.30236	-65.2805	18.3021	-65.28043
Mosquito	18.29205	-65.2631	18.29205	-65.2634	18.29205	-65.26312	18.29205	-65.26341	18.292	-65.2631	18.29199	-65.2634
Puerto Manglar Treatment	18.30606	-65.25169	18.30587	-65.25183	18.30603	-65.25161	18.30576	-65.25172	18.30602	-65.25157	18.30573	-65.25163
Puerto Manglar Control	18.30544	-65.25823	18.30545	-65.25792	18.30557	-65.25825	18.30558	-65.25798	18.30561	-65.25828	18.30569	-65.258
Puerto Manglar Reference	18.30531	-65.25087	18.30518	-65.25103	18.30524	-65.25084	18.30509	-65.25103	18.30523	-65.25082	18.30508	-65.25095

6. Data Management

Data management is the practice of collecting, storing, documenting, and using data efficiently and cost-effectively. The goal of data management is to ensure data access, quality, and integrity. To prevent accidental data deletion/loss, redundant data storage will be utilized to ensure data resides in multiple places and in multiple media. A Seagrass Monitoring Data Google drive folder was created to collate and store all field data.

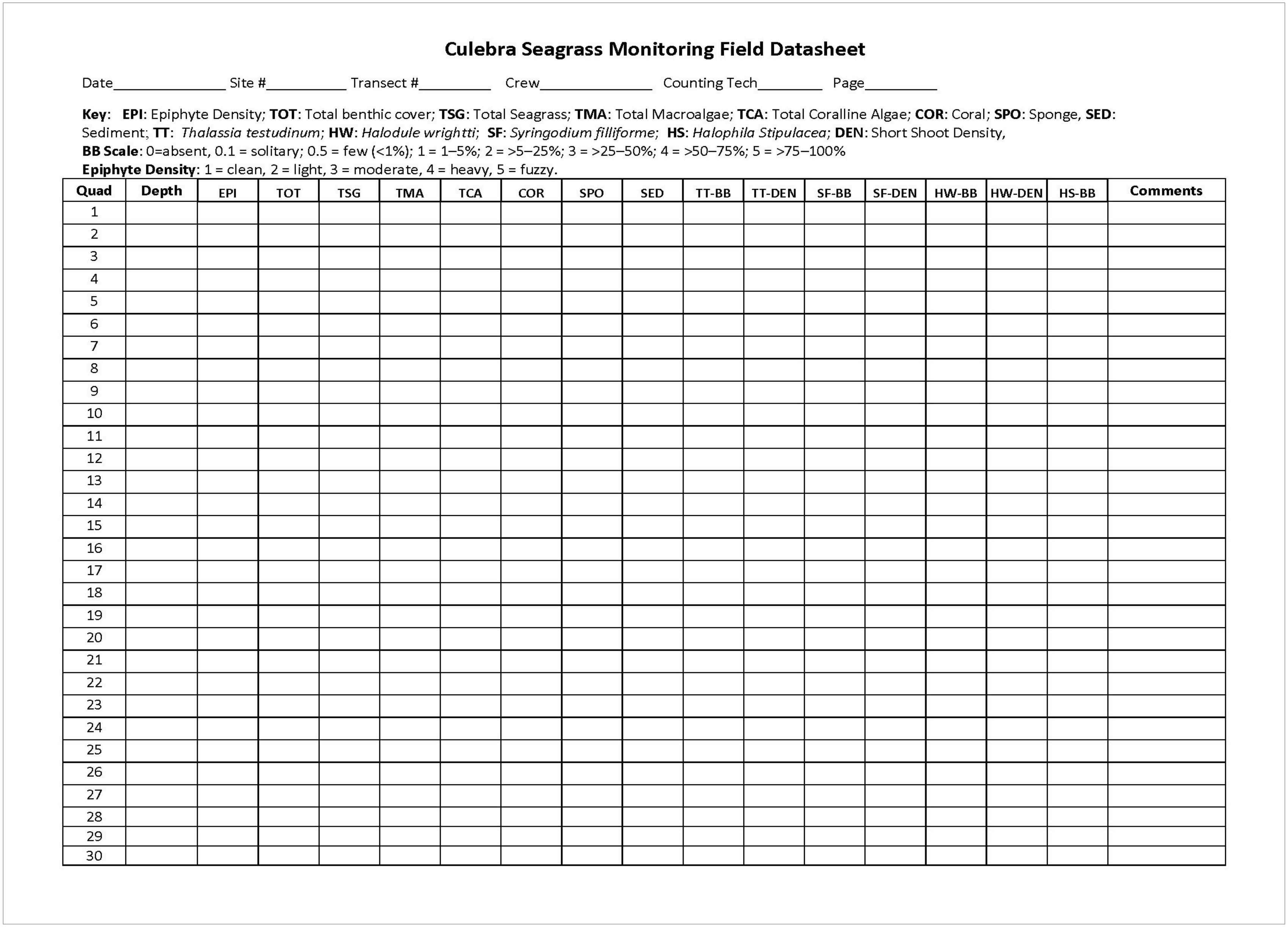
1. For this monitoring effort, data should be stored in at least two permanent repositories at all times:
    a. Durable paper field data sheets.
    b. Excel or spreadsheet form for digital / cloud storage).
2. A durable underwater paper field datasheet (see section 8) will be completed for each transect at each site and subsequently transcribed into a digital format upon returning to the wet lab / hotel room. Field datasheets should be signed by personnel completing data entry.
3. Field data QC process should be completed following data entry and QCed field datasets should be also signed by the personnel completing the QC.
4. Digitally transcribed and QCed datasheets should be scanned and stored.
    a. Hardcopies will be stored in a binder in the Protectores de Cuencas Laboratory. This binder is not to be taken to the field for sampling to prevent previous records from being damaged.
    b. Scanned field datasheets will be uploaded to a shared folder.
    c. It is also good practice to store pre- and post-sampling checklists (see below) in the data binder.
5. Once field datasheets for each monitoring site have been entered, scanned, and submitted the Data Manager/Monitoring Coordinator will upload them to the corresponding folder in the shared Seagrass Monitoring Data Google drive folder.
6. Together with the Data Manager, the Monitoring Coordinator will check the uploaded field for quality and integrity, and request modifications, corrections, and updates as appropriate. Any data changes should be communicated and discussed with the Data Manager prior to implementation.

7. Checklists

Seagrass Transect Monitoring Equipment List

- GPS (spare batteries if handheld)
- Data sheets (On waterproof paper) with extras
- Clipboards and Slates (at least 3) for recording data underwater
- Sharpened pencils
- Pencil sharpener
- Map of transect locations
- Species ID Cheat sheet info
- 100 m fiberglass measuring tape(s)
- 30” rebar and 5 lb sledge hammer
- PVC poles
- Quadrats w/ float & rulers
- Weighted buoy to mark seaward end of seagrass bed
- Magnifying glass (species id)
- Hand Bearing Compass
- Scuba gear or surface supply rig
- Mask & snorkel
- Bathing suit/dive skin/gloves
- Dive booties/water shoes
- Sunscreen
- Hat
- Buff
- Towel
- Lunch & snacks
- Ice & Water
- Change of clothes
- Flagging tape or large zip tie to benchmark shoreward end of transect
- Stakes to use as temporary markings for transects

8. Field Datasheets



Culebra Seagrass Monitoring Field Datasheet

Date______________ Site #__________ Transect #_________ Crew______________ Counting Tech________ Page_________

Key: **EPI**: Epiphyte Density; **TOT**: Total benthic cover; **TSG**: Total Seagrass; **TMA**: Total Macroalgae; **TCA**: Total Coralline Algae; **COR**: Coral; **SPO**: Sponge, **SED**: Sediment; **TT**: *Thalassia testudinum*; **HW**: *Halodule wrightti*; **SF**: *Syringodium filliforme*; **HS**: *Halophila Stipulacea*; **DEN**: Short Shoot Density,
BB Scale: 0=absent, 0.1 = solitary; 0.5 = few (<1%); 1 = 1–5%; 2 = >5–25%; 3 = >25–50%; 4 = >50–75%; 5 = >75–100%
Epiphyte Density: 1 = clean, 2 = light, 3 = moderate, 4 = heavy, 5 = fuzzy.

Quad	Depth	EPI	TOT	TSG	TMA	TCA	COR	SPO	SED	TT-BB	TT-DEN	SF-BB	SF-DEN	HW-BB	HW-DEN	HS-BB	Comments
1																	
2																	
3																	
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9. Estimated Cost

Category	Item Description	Cost per unit	Unit	# Units	Days / Trips	# Persons	Events / Year	Annual Total	Notes
Staff	Project Scientists	$40.00	hour	10	9	3	1	$10,800.00	Estimating 3 scientists; 8, 10-hr day and 2-half days to mobilize and demobilize from Culebra.
Travel	Ferry	$10.00	Roundtrip / person	1	1	3	1	$30.00	3 staff ferry trips.
Travel	Car rental	$100.00	day	9	1	1	1	$900.00	Car rental for one week.
Travel	Gas	$10.00	day	8	1	1	1	$80.00	
Travel	Small boat fuel	$50.00	day	8	1	1	1	$400.00	
Travel	Lodging	$159.00	day	9	1	3	1	$4,293.00	
Travel	Per diem (full days)	$105.00	day	8	1	3	1	$2,520.00	
Travel	Per diem (travel day)	$78.75	day	2	1	3	1	$472.50	
Services	Boat Captain	$300.00	day	8	1	1	1	$2,400.00	Assuming 8 boat days needed to sample all 13 sites.
Equipment	Boat Costs	$700.00	day	8	1	1	1	$5,600.00	Assuming 8 boat days needed to sample all 13 sites.
Equipment	Scuba Tanks/refill	$5.00	tank	9	8	1	1	$360.00	
Equipment	Underwater fiberglass tapes	$50.00	Reel	3	1	1	1	$150.00	Forestry suppliers; 30m fiberglass tapes
Equipment	Supplies: PVC Quadrats, underwater paper	$100.00	Once	1	1	1	1	$100.00	PVC for quadrats, PVC glue, line for grid, UV paper, clipboards
Total							Total	**$28,105.50**	

*Considerable cost savings can be achieved by lodging at PDC field station facility on Culebra.

10. References

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Relevant Links

Seagrasses of southwest Florida - Sea Grant. Eyes on Seagrass. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://sarasotabay.org/wp-content/uploads/Eyes-on-Seagrass-Field-Guides-Seaweed_Seagrasses_PercentCover_Epibionts_FGCUAlgae.pdf

Tampa Bay Seagrass Training Video. https://www.youtube.com/watch?v=jfnVlIjJ-o4&list=PLfJ6-D-exF9RKU6i3A7z0uwfeiyayULqk&index=1