SEAGRASS MONITORING AT THE SOUTHERN COAST OF PUERTO RICO: CAYOS BARCA-JOBOS BAY NATIONAL ESTUARINE RESEARCH RESERVE

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Abstract - Seagrasses are submerged aquatic angiosperm plants that are found very commonly in the coasts of Puerto Rico, especially in the south and east coast of the island. This is the first approach of a seagrass monitoring in the southern coast of the island. We established a submerged aquatic vegetation (SAV) monitoring program, following the NERRS protocol, to track short-term variations and long-term changes in seagrass ecosystems. The general approach used in monitoring seagrass consists of fixed transect with permanent sampling plots located along transect to measure parameters, such as coverage percentage, blue carbon, sedimentation rate, biomass and leaf growth. In SAV monitoring, the results indicated that at higher depth the seagrass coverage decreases. However, the seagrass shoots observed indicate that to more depth the plant's leaves length increases. Results show that the amount of organic carbon (OC) in an area ranges from 0.079 to 0.302. The highest sedimentation rate was found in transect one. Transects two and three had lower sedimentation rate that might be influenced by a channel in the area.

Keywords: seagrass, blue carbon, sedimentation rate, biomass, leaf growth.

Resumen - Las hierbas marinas son plantas angiospermas acuáticas sumergidas que son encontradas comúnmente en las costas de Puerto Rico, especialmente en las costas sur y este de la isla. Este es el primer esfuerzo de un monitoreo de hierbas marinas en la costa sureste de la isla. Establecimos un programa de monitoreo de vegetación acuática sumergida (SAV) siguiendo el protocolo de NERRS para documentar variaciones a corto y largo plazo en los ecosistemas de hierbas marinas. El enfoque general usado en el monitoreo de hierbas marinas consiste en fijar transectos y cuadrantes permanentes en los cuales podamos medir algunos parámetros como porcentaje de cobertura, carbón azul, tasa de sedimentación, biomasa y crecimiento de hojas. En el monitoreo SAV, los resultados indicaron que a mayor profundidad la cobertura de hierbas marinas disminuía. Sin embargo, las plántulas observadas indicaron que a mayor profundidad el largo de las hojas de la planta incrementaba. Los resultados muestran que la cantidad de carbón orgánico (OC) en el área rondaba entre 0.079 y 0.302. La tasa de sedimentación mayor fue encontrada en el transecto uno. Los transectos dos y tres tuvieron la tasa de sedimentación más baja posiblemente por la influencia de un canal en el área donde estaban localizados.

Palabras clave: hierbas marinas, carbón azul, sedimentación, biomasa, crecimiento de hojas.

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Introduction

The Intergovernmental Panel on Climate Change (IPCC) defines *climate change* as "a change in the state of the climate that can persists for an extended period, typically decades or longer and that can be identified using statistical tests" (Wyneken, Lohmann & Musick, 2013). Currently, changes in climate are influencing a variety of organism worldwide; yet, most discussions of global climate change impacts have focused on organisms from temperate to Polar Regions. Impacts to species inhabiting warm climates are often believed to be small in comparison to those living in cooler climates. During the past years, researchers has pointed out that some tropical species, including some marine megafauna, may face potentially serious consequences (Edwards, 2013).

Changes in atmospheric and oceanic temperature will affect coastal ecosystems, by altering precipitation patterns affecting delivery of fresh water, nutrients, sediments, and runoff; altering circulation patterns; increasing ocean acidification; increasing the frequency and intensity of coastal storms; and melting polar ice caps, which will lead to a rise in sea level (Scavia et al., 2002).

Moreover, research in the marine environment was focused on either temperature or sea level rise and their effect on coral reefs and coastal communities. Researchers recently have taken different approaches to study the effect of climate change in marine habitats, such as studying the pelagic zone, subtidal benthos, seagrass, and mangrove habitats, including abiotic factors such as pH and ocean circulation (Wyneken et al., 2013).

Seagrasses are submerged aquatic angiosperm plants found in meadows along the shore of every continent, except Antarctica (Howard et al., 2017). They are very common in the Coasts of Puerto Rico, especially in the south and east coast of the island (García-Ríos, 1990). According to Vicente (1992), seven different species of seagrass were present in Puerto Rico. Currently, seagrass species found in the island include *Thalassia testudinum, Syringodium filiforme, Halodule wrightii, Halophila decipiens,* and *Ruppia maritima* (García-Ríos, 1990). The first three species mentioned are the most common in shallow waters (Otero & Carrubba, 2006). The distribution and depth limit of seagrasses depend on a few physical factors such as wave action, turbidity, light penetration, currents, salinity, substrate, and hydrostatic pressure (Vicente & Riviera, 1982).

According to Wooldridge (2017), coastal seagrass meadows are an essential component of healthy marine ecosystems. Seagrass habitats aid the ecosystem in various ways; for instance, it supports diverse flora and fauna, imparts stability to sediments, and supplies fauna with nursery sites (Pu & Bell, 2017). In Puerto Rico, seagrass meadows are a major food source of turtles and manatees, and the home to many marine organisms like echinoderms, mollusks, and fishes (García-Ríos, 1990; Terrados & Borum, 2004).

Apart from being a highly productive system of significant ecological value, seagrass meadows also have a socioeconomic value, which is one of the reasons why seagrass meadows are being affected (Mutchler & Hoffman, 2017). Aside from the anthropogenic stressors that affect seagrass meadows, other stressors can greatly affect them. As mentioned earlier, the distribution of seagrass meadows depends highly on various ecological factors, which is why researchers can also relate the health of the organism to natural environmental stressors (Dunton, Pulich & Mutchler, 2010). It is also believed that because of the fragmentation caused by waves and currents, animal foraging, and boating on seagrass meadows, mosaics of discrete patches surrounded by a matrix of unvegetated sediment are formed (Siebert & Branch, 2007).

It is believed that climate change has a great effect on seagrass meadows. We established a submerged aquatic vegetation-monitoring program in order to track short-term variations and long-term changes in seagrass ecosystems.

The investigation took place in the Jobos Bay National Estuarine Research Reserve, in the southeast coast of Puerto Rico. Jobos bay was established as a *National Estuarine* Sanctuary in September 1981. According to the Jobos Bay Estuarine Profile, A *National Estuarine Research Reserve* (Laboy, 2002), the reserve is composed of two major areas: Mar Negro, a mangrove-wetlands forest complex, located on the land side of Jobos Bay, Cayos Barca, Cayos Pájaros, and Cayos Caribe, a linear formation of 15 tear-shaped, reef-fringed, mangrove islands extending westward from the southern tip of the mouth of Jobos Bay. The reserve is known to be a very important habitat for endangered species such as the brown pelican (*Pelecanus occidentalis*), the peregrine falcon (*Falco peregrinus*), the Puerto Rican plain pigeon (*Patagioenas inornata wetmorei*), and the yellow-shouldered blackbird (*Agelaius xanthomus*). The hawksbill sea turtle (*Eretmochelys imbricata*) and the West Indian Manatee (*Trichechus manatus*) are often found in the seagrass meadows of the reserve. The National Oceanic and Atmospheric Administration (NOAA), and the Puerto Rico Department of Natural and Environmental Resources (DRNA, for its acronym in Spanish) are in charge of the Reserve management. This investigation will follow the protocols established by the National Estuarine Research Reserve System (NERRS) in 2013.

The profile of the reserve made in 2002 stated that the vast majority of the Reserve has been classified as a conservation sector. These are environmentally sensitive areas, where wetlands, mangrove areas, and scenic outlooks are included because of the protection they require against inappropriate or excessive use. We will be focusing in the seagrass meadows that have not been greatly impacted by anthropogenic factors in this area of the reserve.
According to the NERRS System-Wide Monitoring Program (SWMP) Vegetation Monitoring Protocol (2013) for submerged vegetation communities has the following five objectives. These include the following:

(1) Quantify vegetation patterns and their change over space and time,
(2) Maintain consistency with other monitoring protocols used nationally and worldwide,
(3) Apply over a wide range of estuarine sites and habitats, and for a variety of reserve specific purposes,
(4) Quantify relationships among the various edaphic factors and the processes that are regulating the patterns of distribution and abundance in these communities; and,

(5) Support comprehensive remotely sensed mapping of vegetation communities and other NERRS/SWMP data collection protocols, as well as NERRS/NOAA education, stewardship, and restoration efforts.

In addition, we measured the stored carbon in the soil, the seagrass organic matter, the amount of sediment in a determined period, seagrass leaves growth rate, the total coverage of seagrass and dominant species of the area, and the associated organisms in the seagrass meadows. It is our objective to compare and contrast these measured parameters with other cays in the Jobos Bay reserve. It is important to keep in mind that the purpose of this investigation is to measure the changes in the parameters of seagrass meadows in the study area to identify how much of this changes are due to changes in the environment caused by climate change. Meaning that this investigation is the first step to figure out the effect climate change really has in seagrass meadows of the Jobos Bay reserve.

Methods

The general approach used in monitoring seagrass consists of fixed transects with permanent sampling plots located along a transect that can be stratified or otherwise located within defined segments of the ecotone, mangrove forest, marsh or Submerged Aquatic Vegetation (SAV) bed as described in NERRS SWMP Vegetation Monitoring Protocol (2013). By following the protocol established by NERRS, we will have the opportunity to be consistent with other reserves that are part of the same program, and at the same time be able to compare the results of our investigation to others. As part of the seagrass monitoring, we measured some parameters, such as coverage percentage, blue carbon, sedimentation rate, biomass, and leaf growth, among others.

Study site

According to the reserve profile made in 2002, the temperatures at JBNERR are mainly high throughout the year. At Central Aguirre, the monthly temperatures for the 30-year period between 1968 and 1998 were from 29.7°C (85.4°F) in February, to 32°C (89.6°F) on September 8, 1997, and December 24, 1976, according to the profile. Low temperatures recorded in this period where 13°C (55°F) during the months of November to March. Rainfall data for Central Aguirre recorded during the period stated that the maximum precipitation was in October (7.73 inches), and minimum rainfall occurred in March (1.22 inches). Under steady southeasterly winds, a south-facing coastline, like the south face of Punta Pozuelo and the Cayos, receives wind and swell head-on throughout the day according to the profile. A typical forecast under these conditions is for 1-2 meter (3-5 feet) waves and swell across the exposed southern shelf waters. The profile also states that the conditions are usually much calmer inside the Cayos, with the trend continuing into Jobos Bay. Winds also induce surface currents in the tide channel, which are further augmented by the surface waters of Jobos Bay and the open ocean currents through the fringing Cayos Caribes and Boca del Infierno.

We conducted this investigation in the conservation sector of the reserve in Cayos Barca (Figure 1). According to the NERRS protocol, the study site selected is not affected by natural or anthropogenic factors, and it is representative of estuarine vegetation community in the region. The study site is located near to Boca del Infierno, and it has two red mangrove cays in the south which are divided by a small water channel. Starting from the north of the cays there is an extensive seagrass bed. The study site was composed of four transects: Transect one (N17°55.047' W66° 13.890' / N17°55.059' W66°13.907'), Transect two (N17°55.008' W66°13.939' / N17° 55.056' W66° 13.954'), Transect three (N17° 55.009' W66° 13.954' / N17° 55.042' W66° 13.963') and Transect four (N17° 54.994' W66° 13.974' / N17° 55.025' W66° 13.974'). The depth range of the study site was 0.30-2.35 m with an average of 1.38 m and the tide range 0.46 m.

Figure 1. Location of Jobos Bay National Estuarine Research Reserve and Cayos Barca in Salinas, Puerto Rico (Google maps, 2017).

Submersed aquatic vegetation sampling

To study seagrass beds, we used transects and plots (Moore, 2013). The study area should have at least three or five transects divided equal sections (no less of 10 m between them). The first permanent plot was located at a random distance and the remaining permanent plots were then located at regular intervals along each transect. We used 20 plots in every study site for more comparative data. Each plot was measured with one square meter ($1m^2$) and separated in equal sections between them. The plots were placed with the lower left corner at the chosen point and the rest of the quadrant toward the North. In addition, the seagrass coverage was estimated by using shoot and maximum canopy height within each plot. The canopy height was measured from where the plant emerges from the sediment to the top leaves. The maximum canopy is defined by longest leaves of approximately 90% of the shoots. We use a Braun-Blanquet (1932) scores to measure and determine the seagrass density, as shown in Table 1.

Table 1

Braun-Blanquet density scores

Score	Cover
0	Taxa absent from quadrant
0.1	Taxa represented by a solitary shoot, <5% cover
0.5	Taxa represented by a few (<5) shoots, <5% cover
1	Taxa represented by many (>5) shoots, <5% cover
2	Taxa represented by many (>5) shoots, 5 - 25% cover
3	Taxa represented by many (>5) shoots, 25 - 50% cover
4	Taxa represented by many (>5) shoots, 50 - 75% cover
5	Taxa represented by many (>5) shoots, 75 - 100% cover

Moreover, we carried out an identification of the seagrass species present in the study sites to determine the dominant species. As well, we made an inventory of marine organisms, such as macroinvertebrates, fishes, and macroalgae that use or live in seagrass beds to sustain the importance of this ecosystem.

Blue Carbon

The largest active carbon sink on Earth is the ocean; it absorbs 20–35% of anthropogenic CO_2 emissions (Khatiwala et al., 2009). Coastal wetlands that are acknowledged as important carbon sinks include mangroves, tidal marshes, and seagrasses. This is based on their ability to sequester a large amount of carbon in their biomass and in their soil (Hiraishi et al., 2014). For seagrasses, which is the main interest in this investigation, carbon is sequestered and stored in large amounts through natural capture during photosynthesis or by trapping sediments and natural debris in their complex root systems (Howard et al., 2017). The CO_2 captured during photosynthesis is returned almost immediately to the atmosphere through respiration or, in other cases, it can be stored temporarily in plant foliage. The rest of the CO_2 is often sequestered for a longer period in the biomass and soil (Howard et al., 2017).

For this investigation, we recollected samples of the sediments to analyze and search for blue carbon traces of seagrass meadows along the study area. There are three major carbon pools considered in seagrass meadows: Above ground living biomass (seagrass leaves and epiphytes), below ground living biomass (roots and rhizomes), and soil carbon (Howard et al., 2014). We worked with soil carbon in seagrass meadows in this investigation. We recollected samples using a Hand Corer Sediment Sampler. The core tube of the hand corer has a diameter of 5.08 cm. The sampling areas were at the beginning and end of each transect, with four samples of two areas within transect. We recollected samples, at least, up to 30 cm of depth and then placed in a PVC tube specially modified. A cross-section in the tube was made to make it more accessible for the placement of the samples. The samples were divided into sections of 10 cm unless more strata were identified, in which case the samples will be divided in each stratum. Each piece of the sample was placed in separate plastic bags to take to the laboratory and kept cool for no longer than 48 hours before analysis.

The method to analyze the samples was the Loss-on-Ignition method (LOI) described by LacCore, National Lacustrine Core Facility (2013). The samples were transferred to a crucible and placed in an oven at 100˚C overnight to remove water. Then the sample was placed to cool-down for up to 8-10 hours in a desiccator and weighed. Later on, the samples were placed in a furnace at 550˚C for 5 hours. Putting samples at this temperature will ensure the oxidation of organic carbon. Before we weighed them we let them, cool down once again for a few hours. We will then calculate the LOI (weight %) using the following formula:

$$LOI\ (weight\ \%) = \frac{W_S - W_A}{W_S - W_C}\ X\ 100$$

Where WC is the weight of the crucible with no sample in it; WS is the weight of the crucible with the sample after letting them dry at 100˚C, and WA is the weight of the crucible with the sample after being placed in a furnace at 550˚C. This will give us the total of organic matter in our sample. To acquire the percent of organic carbon in the sample we used the relationship of organic matter (% LOI) with organic carbon (% OC) for seagrasses (Fourqurean, Kendrick, Collins, Chambers & Vanderklift, 2012).

Sediment trap

The sediment traps are commonly used as standard tools for monitoring sedimentation in coral reef environments and seagrass beds and can provide useful information about the relative magnitude of sediment in the study area. The protocol used to monitor sedimentation rate is described in the following literature: *The use (and misuse) of sediment traps in coral reef environments: theory, observations, and suggested protocols* (Storlazzi, Field, & Bothner, 2011) and *An Examination of the Present Condition of Seagrass Meadows in La Parguera, Puerto Rico* (González-Liboy, 1979). Four sediment traps were placed in the selected area. The traps were placed at the beginning or end of transect. The sediment traps consisted of glass vials with a total volume of 0.600 liters. These traps were placed in the ocean floor until the bottom of the glass jar is at reaches 5-10 cm of depth on the substrate. The traps were left in the stations for a period of 7 days (168 hours), and when recollected, they were covered with a cap and taken for analysis to the laboratory. The excess of water inside the jars was removed, also encrusting organisms and other debris was removed. The sample was agitated to homogenized, then a volume of 50 ml was filtered through a glass fiber filter with a pore size of 1.0 μm to collect the sediments. Three sub-samples were made for this step. The sediments were then dried in the oven for 3 hours at 80 oC. Later on, the sediments were allowed to cool before we weigh them. To obtain the sedimentation rate results the following formula was used: $\left(\frac{S}{V}\right) x\ T.$ Where S is the quantity of sediments filtered in grams, V is the volume filtered in milliliters and T is the time in hours the trap was at the study site.

Biomass

For the following procedure, we used the protocol established by Duarte and Kirkman (2001) with some modifications. The instrument used for biomass sampling is a PVC corer sampler (10 cm diameter and 30 cm long). The corer was pushed on the substratum at least 15 cm deep or until the rhizome of the plant around the PVC corer can be cut with a knife. The samples were collected randomly in two quadrants per transect. The samples were placed in labeled (location, number of plot and date) plastic bags and taken to the laboratory in a cooler. They were stored in a cool area for no more than 48 hours before further analysis.

In the laboratory, we determined and separated aboveground and belowground biomass. The above biomass are leaves, flowers and seed, and below biomass are rhizome and roots. The samples were to be washed with seawater to eliminate debris, sediment, and dead tissues. Samples that were not to be processed the same day, they will be rinsed with low-salinity water and store in a cool and dark place. Using a razor blade with the precautions necessary, all epiphytes in the tissue of the plant were removed. The samples are then placed in aluminum boats, and then, placed to dry in an oven overnight at 60˚C to remove the water. Finally, dry samples were transferred to the desiccator to cool and then weigh. The weight of the samples determines the biomass present in the study area. The biomass measured is calculated dividing the dry weight of the sample by the surface area of the substrate sample (g dry wt m-2).

Leaf growth rate

To estimate the growth of seagrass leaves, we used a Plastochrone Method (only leaf length) by Short and Duarte (2001) with some modifications. One transect was randomly selected and the plants that were measured are those in the first and last quadrant of such transect. The leaf length is taken from the meristem to the top of the youngest fully mature leaf. Leaves were marked using a horse needle to create a pinhole in the tissue (meristem). After one week, we cut the marked leaves using scissors and storage them in plastic bags. These were labeled with the date, the number of sample, location, and number of a plot. Afterward, in the laboratory, we measured the new distance of the pinhole using a metric ruler. The leaves collected were put in the oven for 3 hours at 70˚C to determine the biomass (g dry wt) of new leaves and the new growth area of the leaves. Finally, the growth rate (R) was calculated by dividing the new long (NL) into the days (d):

$$R = \frac{N_L}{d}$$

Results

Submersed Aquatic Vegetation Sampling

Transect one has a length of 30 meters and contained four permanent plots located in the meter's three (N17°55.049' W66°13.893'), 11 (N17°55.051' W66°13.898'), 19 (N17°55.054' W66°13.901'), and 27 (N17°55.057' W66°13.905'). The highest coverage of seagrass meadow in this transect was found in the quadrant two with 80% (BB score 5), and quadrant three with 85% (BB score 5). Meanwhile quadrants one and four obtained a lower coverage percentage with 25% (BB score 2) and 45% (BB score 3) respectively. The dominant species in this transect was *T. testudinum* and the co-dominant species was *S. filiforme.* The minimum depth measured was approximately 0.40 m and the maximum depth was approximately 1.30m. The average canopy height of the shoots of T. *testudinum* varied between 12.7-16.5cm. For S. *filiforme* the height varied from 10-20 cm. The organisms observed associated to this transect were three finger leaf alga (*Halimeda incrassata*), leafy Caulerpa (*Caulerpa prolifera*), y-branched algae (*Dictyota sp.*), shaving brush alga (*Penicillus capitatus*), yellowfin mojarra (*Gerres cinereus*), palometa (*Trachinotus goodei*), sea cucumber (*Holothuria sp*.), queen conch (*Lobatus gigas*), barracuda (S*phyraena barracuda*) and back jack (*Caranx crysos*).

Transect two has a length of 90 meters and contained nine permanent plots located in the meter's seven (N17°55.011' W66°13.937'), 17 (N17°55.018' W66°13.940'), 27 (N17°55.022' W66°13.940'), 37 (N17°55.028' W66°13.944'), 47 (N17°55.034' W66°13.945), 57 (N17°55.039' W66°13.946'), 67 (N17°55.044' W66°13.950'), 77 (N17°55.049' W66°13.951'), and 87 (N17°55.055' W66°13.953'). The highest coverage of seagrass meadow was found in the quadrant one with 90% (BB score 5), and quadrant two with 85% (BB score 5). Meanwhile, quadrants eight and nine obtained a lower coverage percentage with 15% (BB score 2) and 20% (BB score 2) respectively. The rest of the quadrants have coverage that fluctuates from 25-45% (BB score 2-3). The dominant species in this transect was *T. testudinum*. The minimum depth measured was approximately 0.30 m and the maximum depth was approximately 2.35 m. The average canopy height of the shoots of *T. testudinum* varied between 18.5-37.5 cm. In this transects the leaves observed were greatly covered by sediments. The organisms observed associated to this transect were three finger leaf alga (*Halimeda incrassata*), green feather alga (*Caulerpa sertularioides*), mermaid fan (*Udotea flabellum*), shaving brush alga (*Penicillus capitatus*), yellowfin mojarra (*Gerres cinereus*), barracuda (*Sphyraena barracuda*), green sea urchin (*Lytechinus variegatus*), amber pen shell (*Pinna carnea*) and west indian sea egg (*Tripneustes ventricosus*).

Transect three has a length of 60 meters and contained four permanent plots located in the meter's three (N17°55.011' W66°13.952'), 18 (N17°55.019' W66°13.955'), 33 (N17°55.027' W66°13.957'), and 48 (N17°55.035' W66°13.957'). The highest coverage of seagrass meadow was found in the quadrant one with 80% (BB score 5), and quadrant two with 75% (BB score 4). Meanwhile, quadrants three and four obtained a lower coverage percentage with 30% (BB score 2). The dominant species in this transect was *T. testudinum.* The minimum depth measured was approximately 0.50 m and the maximum depth was approximately 2.10 m. The average canopy height of the shoots of *T. testudinum* varied between 12.6-42.5 cm. The organisms observed associated to this transect were three finger leaf alga (*Halimeda incrassata*), green feather alga (*Caulerpa sertularioides*), mermaid fan (*Udotea flabellum*), shaving brush alga (*Penicillus capitatus*), barracuda (*Sphyraena barracuda*), green sea urchin (*Lytechinus variegatus*) and west indian sea egg (*Tripneustes ventricosus*).

Transect four has a length of 60 meters and contained three permanent plots located in the meter's 16 (N17°55.006' W66°13.975'), 32 (N17°55.014' W66°13.976'), and 48 (N17°55.024' W66°13.975'). The highest coverage of seagrass meadow in this transect was found in the quadrant one with 80% (BB score 5), and quadrant two with 75% (BB score 4). Meanwhile, quadrants three and four obtained a lower coverage percentage with 30% (BB score 2). The dominant species in this transect was *T. testudinum.* The minimum depth measured was approximately 1.0 m and the maximum depth was approximately 2.35 m. The average canopy height of the shoots of *T. testudinum* varied between 27.2-36.3 cm. The organisms observed associated to this transect were three finger leaf alga (*Halimeda incrassata*), green feather alga (*Caulerpa sertularioides*) and Barracuda (*Sphyraena barracuda*).

Moreover, we can observed other organisms associated to seagrass meadows, such as west indian manatee (*Trichechus manatus*), cushion sea star (*Oreaster reticulatus*), rock boring urchin (*Echinometra lucunter*), yellow jack (*Carangoides bartholomaei*), hound needlefish (*Tylosurus crocodilus*), yellowtail snapper (*Ocyurus chrysurus*), bar jack (*Caranx ruber*), upside-down jellyfish (*Cassiopea xamachana*) and pistol shrimp (not identified).

Blue carbon

The samples measured in this parameter were taken at the first and last quadrant of each transect. After making the mathematical analysis for all replicates of each transect, we obtained the average (avg) organic carbon in the samples. The average range of OC in our samples goes from 0.079 to 0.302.

Sediment trap

At transect one, the trap was placed in the last quadrant (T1, Q4). The average sedimentation rate here was 4.56 x 10-5 g/ml/hr. At transect two, the trap was placed in the last quadrant (T2, Q9) and the average sedimentation rate was 1.75 x 10-5 g/ml/hr. The transect three had an average sedimentation rate of 2.78 x 10-6 g/ml hr., and the trap was placed in the first quadrant (T3, Q1). For the last transect, the trap was placed in the first quadrant (T4, Q1) and the average sedimentation rate of 3.26 x 10-5 g/ml/hr.

Biomass

As mentioned earlier, two quadrants were selected randomly for each transect. For these results, we only took into consideration the seagrass biomass in our area. In transect one, the quadrants selected were two and three with a biomass average of 520.52 and 1156.98 g dry wt m-2 respectively. Moreover, in transect two the randomly selected quadrants were two and six with a biomass average of 1185.35 and 188.72 g dry wt m-2.

The randomly selected quadrants for transect three were three and four with a biomass average of 1308.70 and 63.53 g dry wt m-2. For the last transect, the randomly selected quadrants were two and three and the biomass average in each quadrant was 354.01 and 86.34 g dry wt m-2.

Leaf growth rate

The transect randomly selected for this method was transect two and the plants that were measured were those on the first and last quadrant. For quadrant one the plants that were marked were those on the edges of either extreme of the quadrant. After a week, we recollected 17 marked plants in total from quadrant one. The average growth rate was 0.40 cm/day in such quadrant. The biomass was 0.033 (new growth) and 0.008 (new leaves) g dry wt/day for quadrant number one. In quadrant nine, we marked all of the plants in the quadrant, and after a week, we recollected all four of them. The biomass for this quadrant was 0.013 (new growth) and 0.002 (new leaves) g dry wt. /day. Moreover, the average growth rate was 0.67 cm/day in the same quadrant.

Discussion

In an SAV monitoring, in transects two to four, the results indicated that at higher depth the seagrass coverage decreases. This can be seen in biomass data as well. The main factors that contribute are that at higher depth sunlight decreases in the water column, causing turbidity to increase and photosynthesis to decrease. Meanwhile, the seagrass shoots observed indicate that at higher depth the plant's leaves length increases. Therefore, the plant increases the superficial area and can carry out higher photosynthesis rates. This can be seen in the average leaf growth rate (cm/d) at T2 Q1 and T2 Q9 that was 0.40 and 0.67 respectively. The difference in growth rate in Q1 and Q2, apart from the depth where each quadrant is located, can also be explained by photoinhibition. If the plant is receiving more radiation than require the photosynthetic capacity of photosystem II will be reduced and as a result, the plant's growth rate will decrease (Hanelt & Nultsch, 2003). By comparing these results with the results of González-Liboy (1979), we can see that our values fall in the range of leaf growth rate measured in La Parguera. Their growth rate ranges from 0.29 to 0.79 with an average of 0.61 in the area versus our average growth rate per area, which is 0.54. Moreover, the new biomass (g dry wt d-1) was 0.033 (new growth) and 0.008 (new leaves) for T2 Q1 and 0.013 (new growth) and 0.002 (new leaves) for T2 Q9. In contrast, in transect one, the results were adverse; the major percentage of coverage was in the middle quadrants (Q2 and Q3), meanwhile, the percentage of coverage was low in quadrants one and four. In Q2 and Q3, the habitat conditions are similar, so we would expect that the biomass amount, coverage, shoot counts, and other parameters are comparable. These parameters are similar in both quadrants with the exception in biomass amount (g dry wt m-2). The reason for this difference is that Q2 was the only quadrant where two distinct species of seagrass were collected (*T. testudinum* and *S. filiforme*). *S. filiforme* is morphologically different in comparison with *T. testudinum.* The above and belowground biomass of *S. filiforme* is less than the *T. testudinum*, which means that the combination of both reflects on a reduced amount of biomass content in the results.

Blue Carbon

Results showed that the amount of biomass can affect the amount of organic carbon (OC) in an area. There are more particles and organic matter trapped in the soil when there is a high productivity of biomass (Armitage & Fourqurean, 2016). As shown previously, the average of OC per quadrant per transect shows a difference in values. To analyze the values of the percent of organic carbon in the samples, must take under consideration the large range in ratios of carbon content (OC) to organic matter (%LOI), this will cause the standard ratio values to be sources of possible errors when estimating the organic carbon content (Howard et al., 2014). For transects, one and four OC percentage average was greater in the last quadrants of each transect, which in the case of transect one was quadrant number four and number three for transect four. However, the values observed between quadrants in transect four are very similar. In the case of transect two and three, the greater OC percentage average is in the last quadrants, although values between quadrants for transect three are also very similar. There could be a variety of parameters that can influence these values starting with the amount of biomass in each quadrant. By comparing the values between transects, we can assume that position and length of the transects can also affect the production of OC. All transects were located in an area with a density of mangroves close by that will tend to produce a significant amount of organic matter that in theory will tend to accumulate at the quadrants at the beginning of the transect. The water that comes from the channel located between transect two and three exports a great amount of organic matter due to its location. The depth of the quadrant could also be a parameter that affects the values of this analysis. We propose a further analysis of the sediment at greater depth and water flow in the area to see what other parameters can affect the OC in the sediment.

Sediment trap

The highest sedimentation rate was found in transect one 4.56 x 10-5 g/ml hr., followed by transect four 3.26 x 10-5 g/ml hr. Transect two and three were the ones with the lowest sedimentation rate (1.75 x 10-5 g/ml hr. and 2.78 x 10-6 g/ml hr.) respectively. The value of sedimentation rate of transect three was significantly low from the others, the cause of this could be to the presence of a damselfish (*Stegastes sp.*) that laid eggs in the trap and the fish being in and out of the trap altering the pattern of the sediments that entered the trap. It was also found a significant difference between transects one and four versus two and three in their sedimentation rate values. As mentioned previously, in the study site there is a water channel that is located between transect two and three. This channel may be the influence of the low sedimentation rate in comparison to the other transects. It was also found that transect one had the highest percentage of macroalgae by transects. This result could be associated to the sedimentation rate because an increase in sedimentation is related to the loss of seagrass habitat and giving a competitive advantage to macroalgae (Qiuying & Dongyan, 2014; Holmer, Marba, Lamote & Duarte 2009).

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