

Biomass, productivity and density of the seagrass *Thalassia testudinum* at three sites in Cahuita National Park, Costa Rica

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Abstract: The basic ecology of seagrass beds was investigated by comparing biomass, productivity and density of *Thalassia testudinum* (turtle grass) at three sites: Puerto Vargas, Punta Cahuita and Río Perezoso, in Cahuita National Park, Limón, Costa Rica, over a two month period (March-April 1999). Above ground biomass, density, and productivity were highest in the Puerto Vargas site while Punta Cahuita had the least non-green above ground biomass was significantly lower in total biomass than Puerto Vargas. Punta Cahuita was distinguished by the largest grain size, a very hard substrate, and shallower water. Río Perezoso, on the other hand, had extremely fine sediment and lower salinity, while Puerto Vargas was intermediate both in sediment size and environmental conditions. It appears, therefore, that higher biomass and productivity result from a combination of moderate environmental characteristics and an intermediate sediment size.

Key words: Seagrass, *Thalassia*, Cahuita, Costa Rica, reef lagoon, productivity, biomass.

Seagrass beds are areas of high primary and secondary production in the coastal ecosystems, where they provide important nursery areas for commercially and trophically significant organisms (CARICOMP 1997b), including many fish and invertebrate species (Littler *et al.* 1989). Therefore, seagrass beds serve as good indicators in monitoring the health of the surrounding environment, and play a key role in coastal conservation and restoration projects. Seagrass beds have received considerable attention and many papers have been published, however, this study is the first undertaken in Costa Rica.

Fong and Harwell (1994) have attempted to model seagrass communities, and cite temperature, salinity and light as three of the primary

environmental factors affecting seagrass growth. Other studies support this hypothesis by describing a relationship between higher light levels and increased biomass and productivity (Tussenbroek 1994, Dawes 1998). Positive correlations have also been found between temperature and biomass (Tussenbroek 1995). Although many studies have investigated how light and temperature affect the seagrass beds, little work has been done regarding the relationships between seagrass biomass, productivity and sediment size. This investigation, therefore, attempts to examine the effects of both environmental factors and sediment size on the biomass, productivity, and density of *Thalassia testudinum* in Cahuita National Park, Limón, Costa Rica.

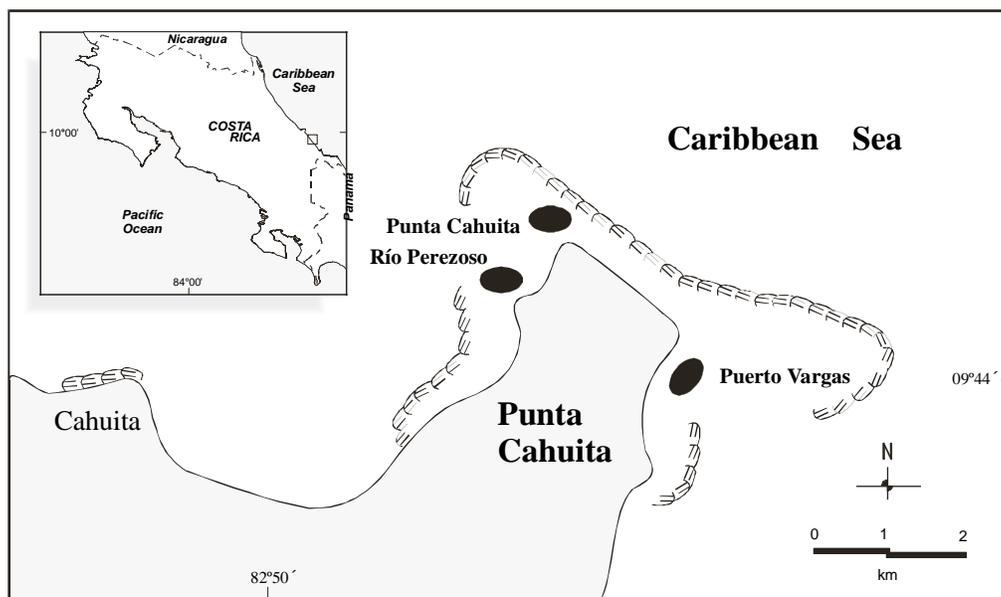


Fig. 1. Location of study sites within Cahuita National Park, Limón, Costa Rica.

MATERIALS AND METHODS

Study site. Seagrass beds were studied in Cahuita National Park, Limón, Costa Rica, in three coral reef lagoon sites (Fig. 1). The sites were chosen from the most luxuriant or well-developed *Thalassia* community with clean, green leaves that differed in substrate, but which did not differ significantly in water temperature or visibility.

The first site, Puerto Vargas, was located approximately 25 m offshore on the south side of Punta Cahuita ($9^{\circ}44'38.2''\text{N}$; $82^{\circ}48'32.7''\text{W}$). The substrate was composed of intermediate size fragments, and wave action was relatively strong. Moderate tourist activity at this site included some snorkeling and swimming. The second site, Punta Cahuita, was located approximately 75 m north of Punta Cahuita ($9^{\circ}45'02.3''\text{N}$; $82^{\circ}48'58.7''\text{W}$). Sediments were coarse (\geq medium sand), and a hard substrate was encountered approximately 20 cm below the sediment surface. A strong current was also noted at this site with minimal wave action. Tourist activity including boat tours, swimming, snorkeling and walking on the reef (Gove and Cortés in prep.). The final site, Río Perezoso, was located about 20 m west of Punta Cahuita

($9^{\circ}44'13.3''\text{N}$; $82^{\circ}48'24''\text{W}$) approximately 75 m south of the mouth of Río Perezoso. The sediment was fine and soft, and there was almost no current or wave action. Tourist activity is minimal.

Environmental monitoring. Measurements were taken in accordance with the methodology outlined by CARICOMP (<http://www.uwimona.edu.jm/centres/cms/caricomp>; description of the program and methods manual can be found at this internet site). Air temperature, water temperature (both with mercury thermometers) and water depth were measured every Monday, Wednesday, and Friday between 10:00 and 12:00 local standard time, between March and April 1999. Weekly, visibility was measured horizontally with a Secchi disk, and water samples were taken back to the laboratory where salinity was measured with a refractometer.

Biomass. Three cores, 30 cm deep, were taken from each site (four from each Río Perezoso subsite) using a corer built to CARICOMP regulations (20 cm diameter PVC). The samples were refrigerated until they were transported to the laboratory for processing. Core samples were cleaned of sediment (retaining 300 g for sediment size analysis) and separated into green

leaves, non-green leaves, live rhizomes and roots, and dead belowground material. Samples were rinsed in 10% hydrochloric acid to remove epiphytes and dried at 60°C for at least 36 hours.

Growth rates. Four 10 x 20 cm quadrats were randomly placed at each site and the leaves marked with a hypodermic needle at the green-white interface or at the sediment surface. After seven to ten days the leaves were harvested at the sediment surface; noting visibility and water temperature both at the time of marking and at the time of collection. The number of shoots per quadrat was recorded at the time of harvesting as a measure of density. Three growth rate samples were taken during the two-month study, and the leaves were stored refrigerated until transportation back to the laboratory. At the laboratory, leaves were washed in 10% hydrochloric acid to remove epiphytes, clipped at the needle punch mark, and separated into four groups: new leaves that have emerged since marking (group 1), new growth of leaf below the punch mark (group 2), length of leaf above the punch mark (group 3), and leaves in which the hole was indistinguishable (group 4). Samples were dried at 60°C for at least 36 hours and weighed.

Sediments analysis. Sediment samples were gathered from each site from the biomass cores, dried for 48 hours at 60°C and subjected to a mechanical granulometric analysis which divided the sediments into five size classes: gravel (50.80-4.75 mm diameter), coarse sand (2.0-4.75 mm), medium sand (0.25-2.00 mm), fine sand (0.15-0.25 mm), and fine sediment (< 0.15 mm).

Data analysis. Above and below ground biomass, total biomass and the above/below ratios were calculated for each core sample. Productivity was calculated from the growth rate samples by the equation: [(groups 1 + group 2) days⁻¹] x 50 to determine production per square meter per day (CARICOMP 1994). This number was corrected to account for the indistinguishable leaves: group 4 was multiplied by the ratio of group 2/(group 2 + group 3) and this value was added to group 2 in the original equation. Turnover rate (% growth day⁻¹) was also calculated from the growth rate samples. The sum of groups 1 and 2 was divided by the standing crop (sum of groups 1, 2 and 3) and multiplied by one hundred.

One-way ANOVA tests were used to compare the environmental measurements, biomass, and sedimentary data between the three sites. If the means were significantly different, Tukey's HSD procedure for multiple comparisons was used to analyze data in which sample sizes were equal and Scheffe's test was used to compare means with unequal sample sizes. Two-way ANOVA tests were used to compare density and productivity means between sites and over time. Scheffe's test procedure was employed for post-hoc comparisons when significant difference was found. All ANOVAS were tested for homoscedasticity and a log 10 transformation was used for the following variables in which the assumption was not met: visibility, fine sediments, density and turnover rate. In the case of dead underground biomass it was necessary to use the non-parametric Kruskal-Wallis test.

RESULTS

Water depth and salinity were the only environmental variables that differed significantly between sites (Table 1). The water depth at Punta Cahuita was half as deep as the other two sites with an average of 0.36 m, and Río Perezoso had a lower average salinity of 35.8.

Total biomass differed significantly between Puerto Vargas and Punta Cahuita with Puerto Vargas being the higher of the two sites with a value of 1309.69 g m⁻² (Table 2). In aboveground biomass (499.42 g m⁻²) and the aboveground/belowground ratio (0.617), Puerto Vargas was the highest of the three sites. Non-green aboveground biomass varied significantly between all three sites with the highest mean (345.21 g m⁻²) at Puerto Vargas and the lowest (112.41 g m⁻²) at Punta Cahuita. Puerto Vargas also had the highest green leaf biomass (154.21 g m⁻²). Underground biomass showed no significant variation between sites, and dead underground material was significantly lower at Punta Cahuita (0.052 g m⁻²).

Although no significant differences were found between sites in turnover rate (Table 3), production was highest in Puerto Vargas with a mean of 4.16 g m⁻² day⁻¹. Density was also significantly higher in Puerto Vargas, averaging 2460 shoots m⁻².

TABLE 1

Comparisons between environmental conditions at three sites in Cahuita National Park, Costa Rica

	Puerto Vargas	Punta Cahuita	Río Perezoso	p-value	d.f.
Air temperature (°C)	25.7±1.70	25.5±0.94	25.2±1.17	0.617	2
Water temperature (°C)	28.4±1.57	28.2±1.33	28.3±1.84	0.965	2
Visibility (m)	3.9 ±0.26	5.1±0.25	3.2±0.23	0.084	2
Water depth (m)	0.7±1.19	0.4±0.19*	0.6±0.13	0	2
Salinity	37.1±1.11	37.23±1.01	35.8±1.34*	0	2

Asterisks denote values that are significantly different by one-way ANOVA followed by Tukey's HSD procedure for multiple comparisons.

TABLE 2

Comparisons between Thalassia testudinum biomass (g m⁻²) at three sites in Cahuita National Park, Costa Rica

	Puerto Vargas	Punta Cahuita	Río Perezoso	p-value	d.f.
Green leaves	154.21±38.77	68.24±27.90	79.34±18.62	0.003	2
Non-green leaves	345.21±19.55*	112.41±23.96*	185.03±38.86*	0	2
Above ground	499.42±46.44	180.65±13.24	264.37±51.84	0	2
Roots-rhizomes	810.27±1.72	600.95±1.75	793.36±3.70	0.230	2
Dead below ground	0.41±5.49	0.05±0.78	1.28±40.68	0.025	2
Above/Below ratio	0.62±0.01	0.30±0.03	0.34±0.03	0	2
Total biomass	1309.69±137.91*	781.60±103.55*	1057.73±244.87	0.031	2

Asterisks denote individual values which are significantly different from one another determined by one-way ANOVA followed by Tukey's HSD procedure for multiple comparisons. The biomass of dead underground material did not meet the assumption for homoscedasticity and was compared using the Kruskal-Wallis test.

TABLE 3

Comparisons in productivity and shoot density of Thalassia testudinum between three sites at Cahuita National Park, Costa Rica

	Puerto Vargas	Punta Cahuita	Río Perezoso	p-value	d.f.
Turnover rate (% day ⁻¹)	4.18	3.81	3.69	0.381	2
Production (g m ⁻² day ⁻¹)	4.16*	2.39	2.4	0	2
Density (shoots m ⁻²)	2460*	1600	1418	0	2

Asterisks denote values which are significantly different by one-way ANOVA followed by Tukey's HSD procedure for multiple comparisons.

The sediment at the three sites were characterized by a particular size gradient (Fig. 2). Punta Cahuita had the largest sediment size, with a significantly higher percentage of medium sand than the other two sites ($p = 0.0281$, d.f.

$= 2$) (Fig.2). Puerto Vargas was the intermediate in substrate size with the statistically highest percentage of fine sand ($p = 0.0024$, d.f. = 2), while Río Perezoso had the smallest sediment with the highest percentage of fine sediments of

Fig. 2. Sediment size distribution between the three study sites in Cahuita National Park.

the three sites ($p = 0.005$, d.f. = 2). Neither the categories gravel nor coarse sand differed significantly between the sites ($p = 0.0448$, d.f. = 2; $p = 0.0541$, d.f. = 2).

DISCUSSION

The environmental conditions at Cahuita National Park were similar to those at the other CARICOMP sites. Cahuita's average air temperature of 25.5°C fell within the median (21.7-27.7°C) temperature range for 42 other Caribbean sites and placed it just slightly below the average of 26.6°C (CARICOMP 1997a). The average Cahuita water temperature of 28.3°C was just above the CARICOMP average of 27.6°C (CARICOMP 1997a). Visibility varied widely between the CARICOMP sites, ranging from 2-30 m (CARICOMP 1997a). The visibility at the Cahuita sites was on the lower end of this range, varying from 3.24-5.10 m. This is not surprising as the coral reef in Cahuita National Park is suffering from increased siltation stress thought to be a result of deforestation (Cortés and Risk 1985).

When looking at biomass at each site, Puerto Vargas had the highest values for all categories of above ground biomass, but did not differ significantly from the other sites in measured environmental factors. Three possible hypotheses are suggested to explain the higher biomass at this site. First, environ-

mental extremes in the other two sites may limit seagrass growth. Another possibility is that substrate composition, which differed significantly between all three sites, has a strong influence on seagrass biomass and productivity. Finally, the higher biomass at Puerto Vargas may have resulted from an environmental factor not taken into account by this study.

In analyzing the first hypothesis, it is important to note that shallow water depth at Punta Cahuita could have both positive and negative effects on the biomass of *T. testudinum*. Studies have shown that biomass and productivity are higher in shallow waters because of increased light irradiance (Dawes 1998). However, water depth at Punta Cahuita can drop as low as 10 cm. Such extremely shallow depths may inhibit seagrass growth by exposing leaves to high light irradiation and increased water temperatures. Therefore, it is difficult to quantify whether the shallower depth at Punta Cahuita enhanced or limited seagrass biomass.

It appears unlikely that the lower average salinity at Río Perezoso affects the seagrass biomass. Resulting from periodic outflow of the river after heavy rains, this may add to the variability of environmental conditions at the site but falls almost exactly at normal oceanic conditions, which are around 35 ppt.

Investigating the second hypothesis reveals a correlation between sediment size and *T. testudinum* biomass. Punta Cahuita had a higher

percentage of medium size sediment and significantly lower above ground biomass than the other two sites. In addition, sediment at the Punta Cahuita site was much harder and shallower than the other two sites, which would require more energy for root and rhizome growth leading to less aboveground biomass. Río Perezoso, at the other extreme, had the highest percentage of fine sediment that also appeared to hinder growth of seagrass leaves by coating them with a layer of sediments thereby limiting light for photosynthesis. In addition, it was noted that the Río Perezoso river sediment was dark brown, whereas the substrate in Puerto Vargas and Punta Cahuita was carbonate based and white. Although the sites did not differ in visibility, it is likely that there was less light in the water at the Río Perezoso site, as the light would be absorbed rather than reflected by the suspended sediment. In Puerto Vargas, the substrate was dominated by a sediment size between 0.15-0.25 mm. It appears that this size class enhances seagrass growth as it is small enough to permit free growth of roots and rhizomes and large enough not to create a light-blocking film on the leaves.

Although the higher biomass and productivity of Puerto Vargas could be attributed to the sediment structure and moderate environmental conditions, an environmental factor not measured in this study may be responsible for the difference. Fong and Harwell (1994) cite nutrient concentration in both the substrate and the water column to be primary environmental factors affecting seagrass growth. In addition, other studies have found high nutrient levels in the water to result in decreased biomass (Tomasko and Lapointe 1991, Tussenbroek *et al.* 1996). It is possible that nutrient levels are significantly higher at the Río Perezoso resulting from river outflow. The Río Perezoso originates in swampy conditions and the water is brown from a high concentration of tannins.

Turnover rate did not vary significantly among the three sites, indicating that the rate of individual plant growth may not be strongly affected by sediment size. It is also possible that turnover rate is affected by factors that did not vary between the sites.

Production, however, was significantly higher in the Puerto Vargas site. As a measurement of

productivity per unit area, higher productivity results from the higher shoot density of *T. testudinum* in Puerto Vargas. Higher density at the site corresponds in turn with the previously discussed higher above ground biomass in Puerto Vargas. Differences in productivity and density, therefore, can be attributed to the same environmental and sediment conditions believed to influence aboveground biomass.

Total biomass values in Cahuita National Park were in the midrange of data from the other CARICOMP sites, the majority of which had total biomass of approximately 1000 g m⁻² (CARICOMP 1997b). These values correspond with the findings of Dawes (1998) in which biomass ranged from 472-1560 g m⁻².

The median turnover rate among the CARICOMP sites, approximately 3% day⁻¹ (CARICOMP 1997b), is below the values for Cahuita (3.69-4.18% day⁻¹). The Cahuita values are also comparable to those found in a study by Tussenbroek (1995), which ranged from 3.35-5.16% day⁻¹ and were higher than the results of Tomasko and Lapointe (1991) who found turnover rates to be 1.11-2.83% day⁻¹.

Productivity of *T. testudinum* in Cahuita National Park was also similar to other CARICOMP sites, the majority of which ranged from 1-3 g m⁻² day⁻¹ (CARICOMP 1997b). Productivity at the Puerto Vargas site, however, was somewhat higher with a value of 4.16 g m⁻² day⁻¹. This value also appears to be greater than studies in Mexico and the western Caribbean that ranged in productivity from 0.88-1.49 g m⁻² day⁻¹ (Tussenbroek 1995) and 0.306-1.372 g m⁻² day⁻¹ (Tomasko and Lapointe 1991), respectively.

Biomass and productivity of *T. testudinum* in Cahuita National Park appears to be average to high in relationship to the other sites around the Caribbean even though visibility is relatively low. Perhaps this can be accounted for by the fact that the study sites were shallower than the CARICOMP standard of 1.5 m (CARICOMP 1994). Seagrass beds were difficult to find deeper than 0.8 m at Cahuita National Park, suggesting that *T. testudinum* is growing in shallower water to compensate for lower visibility.

Above ground biomass, shoot density, and productivity of *T. testudinum* were greater at the Puerto Vargas study site. Punta Cahuita, on the other hand, had the lowest value for

non-green above ground biomass and was significantly lower than Puerto Vargas in total biomass.

When the environmental differences between the sites were analyzed, variations in biomass and productivity appeared to correlate most strongly with the nature of the sediment and its size. Therefore, it appears that substrate composition is the definitive factor affecting seagrass growth in Cahuita National Park. This suggests that moderate environmental conditions and intermediate sediment size are conducive to high levels of *T. testudinum* growth.

Environmental variables not taken into account in this study were nutrients in the sediment, nutrients in the water column, and amount of light in the water column. Further research into these variables would be valuable to gain a more complete understanding of the effects of the environment on *T. testudinum* growth. A year-round study would also be useful to investigate both the extent and effects of seasonal variation at Cahuita.

This study provides an assessment of average *T. testudinum* biomass and productivity at Cahuita National Park. Therefore, this data can be used as a basis for comparison with future studies to monitor the health of the seagrass beds in Cahuita National Park. Furthermore, this data can be compared with similar data gathered from CARICOMP sites around the Caribbean to investigate the health of the Cahuita coastal ecosystem and the Caribbean coastal ecosystems in general.

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RESUMEN

Se investigó la ecología básica del pasto marino *Thalassia testudinum* (pasto de tortu-

ga), comparando biomasa, productividad y densidad, en tres sitios en el Parque Nacional Cahuita, Costa Rica: Puerto Vargas, Punta Cahuita y Río Perezoso. Se tomaron muestras de biomasa, sedimentos, crecimiento y densidad durante dos meses (marzo y abril, 1999), además se midió la temperatura del aire y agua, la visibilidad, la profundidad, y la salinidad. La biomasa de hojas, densidad y productividad fueron más altas en Puerto Vargas. Punta Cahuita tuvo la menor biomasa de hojas que no eran verdes y fue menor que Puerto Vargas en biomasa total. Punta Cahuita se caracterizó por tener sedimentos gruesos, el substrato duro y la profundidad baja, mientras que Río Perezoso tenía sedimentos muy finos y la salinidad más baja. Puerto Vargas era intermedio en ambos: tamaño de sedimentos y condiciones ambientales. Parece que la biomasa y la productividad alta resultan de la combinación de características ambientales moderadas y el tamaño de sedimentos intermedios.

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