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NUTRITIONAL COMPOSITION OF FOOD ITEMS CONSUMED BY ANTILLEAN MANATEES (*Trichechus manatus manatus*) ALONG THE COAST OF PARAÍBA, NORTHEASTERN BRAZIL

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ABSTRACT

This study assessed the nutritional composition of 31 food items consumed by Antillean manatees in the estuary of the Mamanguape River Mouth, state of Paraiba, northeastern Brazil. Samples were collected during dry and rainy seasons, and analysed levels of dry matter, crude protein, neutral detergent fiber, acid detergent fiber and mineral matter. Brown algae had higher neutral detergent fiber content (up to 60,68%) than observed in mangroves (up to 59,99%), but lower than the highest values found in aquatic macrophytes (up to 74,99%) and *Halodule wrightii* (up to 69,04%). When this marine angiosperm is not readily available and Antillean manatees can access the margins, *Rhizophora mangle* roots and *Blutaparon portulacoides* and *Sesuvium portulacastrum* stems can supplement a fiber-rich diet, with 59,99%, 48,96% and 47,45% fiber, respectively. Supplementation in fresh water can be attained by eating mangrove leaves, since those have a high moisture content, up to 77,81%. The highest values of protein (up to 29,55%) were found in *Hypnea musciformis*, especially in the rainy season. Nutritional composition of the food may vary with geographic location and the method of collecting, drying and washing the material. This study may support other studies on the nutritional requirements of Antillean manatees in Brazil and assist in the development of basic maintenance diets for captive animals.

1. Introduction

The two living families representing the order Sirenia are strictly herbivorous, non-ruminant, fully adapted to aquatic life and consist of: Trichechidae (American manatee, *Trichechus manatus*; African manatee *Trichechus senegalensis*; and Amazonian manatee, *Trichechus inunguis*) and Dugongidae (dugong, *Dugong dugon*) (HINES et al., 2020). In Brazil, both Amazonian and American manatees occur, the latter occupying coastal areas, rivers, and estuaries and is a subspecies, Antillean manatee (*Trichechus manatus manatus*). The subspecies is distributed from the southeastern United States to the northeast coast of Brazil (LUNA et al., 2011).

The distribution of Antillean manatees coincides with that of freshwater sources and seagrasses and macroalgae that serve as their food (LUNA et al., 2011). This aquatic vegetation is consumed at a rate of 5 to 10% of the animals' body weight per day (REEP and BONDE, 2006) As in other shallow and estuarine coastal areas around the world, these food resources are affected by anthropogenic activities, with consequent reduction in coverage (SHORT et al., 2006; CECCHERELLI et al, 2007; PITANGA et al., 2012).

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American manateesare listed as “Endangered” in the Official Brazilian National List of Endangered Fauna Species (ICMBIO, 2014a), and as “Vulnerable” in the Red List of the International Union for the Conservation of Nature and Natural Resources, while the Antillean manatee is classified as "Endangered" (DEUTSCH et al., 2008). In order to minimize the impact the species has suffered in recent years, rescued animals, especially orphaned calves, are sent to rehabilitation centers (LUNA et al., 2011). In these units, individuals are fed milk formulas and, when adults, seaweed, needle grass, lettuce, carrots, beets, bananas, apples, and other vegetables and fruits (VERGARA et al., 2000; LAZZARINI et al., 2014).

Feeding care of marine mammals is often addressed through experiments with a particular species or groups of individuals, and this can make it difficult to estimate American manatees real basic needs (WORTHY, 2001).

In the Northeastern region of Brazil, the food items that make up the Antillean manatee diet are known and include green, brown, and red algae, phanerogams and cnidarians (BORGES et al., 2008). In Northern Brazil, consumption of a wide variety of submerged, floating, and emerging plants was observed (RODRIGUES et al., 2016). Vegetation may be reached by sirenians in its entirety (when the rhizomes are accessible) or partially (when only the leaves are accessible) (ARAGONES et al., 2006; MARSHALL et al., 2003). This behavior may be associated with the fact that the bromatological composition of food items varies according to the part of the plant ingested (WERNER, 1993), as well as the species, age, time of year and soil fertility (SIEGAL-WILLOTT et al., 2010; WERNER, 1993).

Although current information available about the diet of Antillean manatees in Brazil can be considered relevant, more specific scientific information about their feeding habits is necessary. Studies with American manatees can advance by combining studies of daily rates of food intake with energy needs, digestive efficiency, and nutritional and energetic compositions of potential foods (WORTHY and WORTHY, 2014). Thus, the objective of this study was to analyze the nutritional composition of foods consumed by Antillean manatee (*T. manatus manatus*) in the estuary of the Mamanguape River, state of Paraíba, Brazil, to support new research on digestibility, digestive efficiency and nutritional requirements of Antillean manatees, and assist in the development of basic maintenance diets for captive animals.

2. MATERIAL AND METHODS

2.1. Study area

The samples were obtained from the Mamanguape River Mouth Environmental Protection Area (EPA Mamanguape) and from the Area of Relevant Ecological Interest (AREI), Mangroves of the Mamanguape River mouth (AREI Mamanguape). These areas are located in the northern coastal region of the state of Paraíba (Brazil) and include the estuarine portion of the Miriri and Mamanguape rivers. The latter is about 25 km long, has satisfactory turbidity (below 100NTU) and Total Dissolved Solids (TDS) above the indicated (>500 mg /L) (ICMBIO, 2014b). The highest tidal currents are observed during the ebb stage and the lowest during the flood stage. At its of the Mamanguape river mouth, the wave climate is different from the oceanographic aspects of the riverbed due to the presence of a line of reefs that stretches along the coast and softens the direct action of the waves. The collection sites (n = 11) were indicated by animal handlers from the EPA Mamanguape and field assistants from the Aquatic Mammals Foundation, based on previous findings on foraging areas of Antillean manatees (Fig. 1).

2.2. Selection and processing of food items

For the selection of food items, the sole publication that previously reported the food consumption of Antillean manatees in the state of Paraíba (BORGES et al., 2008) was considered, as well as information obtained through structured interviews with four animal keepers from the EPA Mamanguape and the AREI Mamanguape, and one field assistant from the Aquatic Mammals Foundation. These interviewees have extensive experience in the study area, are knowledgeable about the eating habits of Antillean manatees and answered three questions: "how long have you known the Antillean manatee?", "in what locations did you see the Antillean manatee eat?" and "what did it eat?".

The food items constituting the Antillean manatee diet were manually collected during the rainy and dry periods, by autonomous scuba dives and apnea. The samples were obtained randomly from meadows of marine angiosperms, banks of epiphytic macroalgae, mangroves, and regions of aquatic macrophytes, stored in plastic bags, frozen (-20 °C), identified and washed with distilled water. In the laboratory, samples

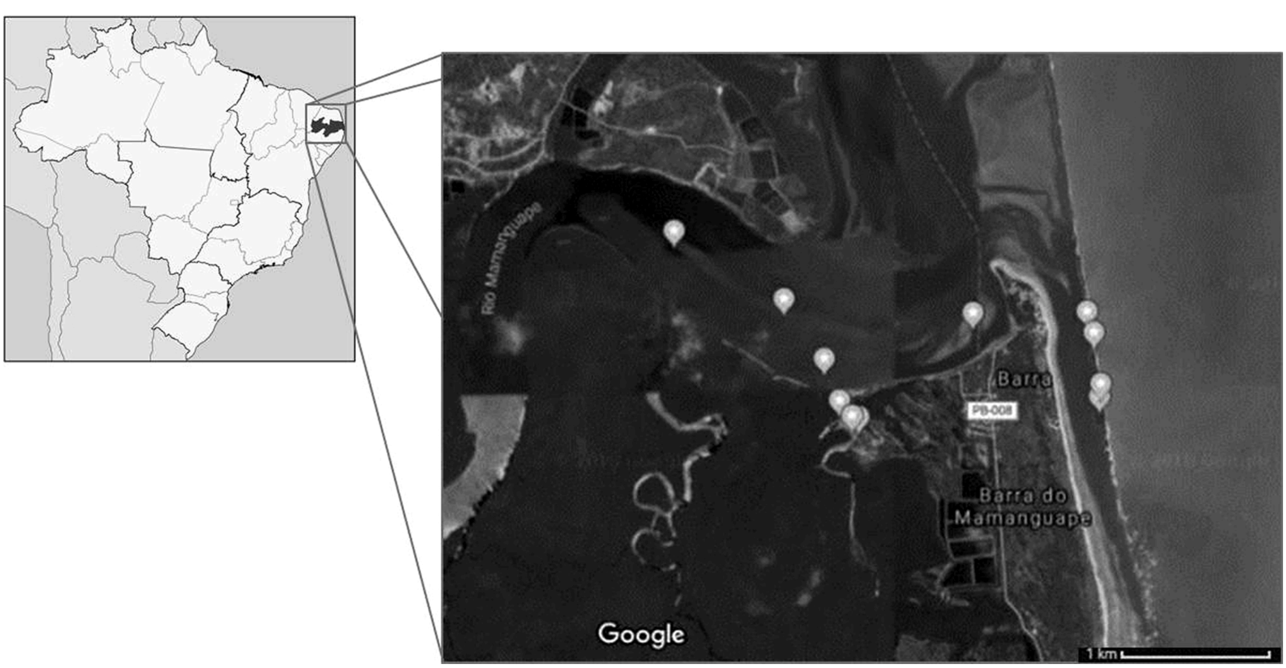

Fig. 1. Geographic location points of the collections in the Mamanguape River Mouth estuary/PB.

were subjected to the determination of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and mineral matter (MM) – according to AOAC Association Of Official Analytical Chemist, 1984, using the Weende and Van Soest method, at the Animal Nutrition Laboratory of the Zootechnics Department of the School of Veterinary and Zootechnics, Federal University of Goiás (LANA / DZO / EVZ / UFG). After grinding, food items less than 6 g, insufficient to determine all nutrients, were discarded.

To assess the quality of the environment from which the food items derived and ensure that the evaluated foods are healthy, water samples were collected at two points on the Mamanguape River (estuary and continental area), during the dry and rainy periods, in the low tide range. The samples obtained were subjected to qualitative analysis of turbidity, dissolved oxygen, biochemical oxygen demand, hydrogen potential, ammoniacal nitrogen, phosphate, temperature and sedimentary material, using a monitoring kit and methodology developed by Branco and Rocha (Fundação SOS Mata Atlântica. Observando os rios, 2017) to measure the Water Quality Index (WQI).

The data variance analysis was performed using the R software (version 3.4.2), comparing the nutritional values of the foods available in each period of the year (rainy and dry), with the objective to know at what time of the year food can be provided in captivity to support different clinical cases. The results of the nutritional composition were obtained by calculating the arithmetic mean of the duplicates in each period of the year.

3. RESULTS

Up to 1,120 g per food item was collected (Table 1), according to the availability of each species.

Table 1
Collected food items consumed by Antillean manatees (Trichechus manatus manatus) in two periods of the year (rainy and dry).

Taxonomic group	Code	Food item (whole, unless otherwise noted)	Green sample (g)	
			Rainy period	Dry period
Green algae	1	*Caulerpa cupressoides*	15	669
	2	*Caulerpa mexicana*	444	314
	3	*Caulerpa prolifera*	0	711
	4	*Caulerpa racemosa*	165	403
	5	*Caulerpa sertularioides*	10	480
	6	*Ulva* sp.	380	871
Brown algae	7	*Dictyota mertensii*	65	28
	8	*Dictyopteris deliculata*	235	399
	9	*Sargassum* sp. 1	625	832
	10	*Sargassum* sp. 2	115	0
Red algae	11	*Amansia multifida*	181	490
	12	*Cryptonemia crenulata*	933	839
	13	*Gracilaria caudata*	376	518
	14	*Gracilaria domingensis*	15	617
	15	*Gracilaria obtusata*	1,037	653
	16	*Gracilaria* sp.	20	0
	17	*Gracilaria* sp. 1	90	167
	18	*Gracilaria* sp. 2	55	701
	19	*Gracilaria* sp. 3	45	711
	20	*Gracilaria* sp. 4	10	0
	21	*Hypnea musciformis*	611	832
	22	*Laurencia* sp.	270	0
Aquatic macrophytes	23	*Blutaparon portulacoides*	856	930
	24	*Eichhornia* sp.	475	0
	25	Poaceae	1,039	608
	26	*Sesuvium portulacastrum*	897	904
Mangroves	27	Leaves of *Avicenia schaueriana*	447	792
	28	Leaves of *Laguncularia racemosa*	1,120	968
	29	Leaves of *Rhizophora mangle*	457	1,057
	30	Root of *Rhizophora mangle*	1,055	789
Marine Angiosperms	31	*Halodule wrightii*	135	156

The results of the nutritional composition varied among food items/groups (Table 2). The highest values of neutral detergent fiber content were found in aquatic macrophytes and marine angiosperms in rainy and dry period, respectively. Thus, the Poacea - leaf were higher in fiber content (78,26%), followed by the *Halodule wrightii* (69,04%). Brown algae and mangroves also had a high neutral detergent fiber content: *Sargassum* sp. 2 (60,68%) in rainy period and *Rhizophora mangle* - root (59,99%) in dry period.

Supplementation in fresh water can be attained by eating mangrove, especially of species *Laguncularia racemosa* - whole in rainy period, since they have a high moisture content (77,81%). The highest values of protein were found in *Hypnea musciformis*, especially in the rainy season, with 29,55%.

For *Caulerpa cupressoides*, *C. prolifera*, *C. sertularioides*, *Ulva* sp., *Dictyota mertensii*, *Dictyopteris deliculata*, *Gracilaria domingensis*, *Laurencia* sp., *Blutaparon portucaloides* - leaf and root, *Eichhornia* sp., Poacea - leaf and root, *S. portulacastum* - stem, *Avicenia schaueriana* – whole structure, *Laguncularia racemosa* - florescence, *R. mangle* - root, the variance analysis showed a significant difference ($p < 0.005$) in nutritional composition between the dry and rainy periods. Therefore, they can be inserted in the formulation of diets with attention to the period of the year in which the diet will be provided.

The physico-chemical parameters were obtained in the qualitative assessment of the water quality of the Mamanguape River and they show that the water has regular quality, acceptable for the development of healthy foods (Table 3).

4. DISCUSSION

The geographical distribution of the American manatee is associated with the choice of feeding areas with greater diversity and availability of food items, as opposed to those rich in nutrients, making this animal less specialized in its feeding strategies (CASTELBLANCO-MARTÍNEZ et al., 2012; WORTHY and WORTHY, 2014) or able to supplement its diet nutritionally by eating different plant species (COLARES and COLARES, 2002). Although algae consumption is documented as not significant in the diet, as it is ingested secondarily to vascular plants (aquatic and mangrove), which are rich in cellulose and require microbial fermentation (CASTELBLANCO-MARTÍNEZ et al., 2009, 2012; WORTHY and WORTHY, 2014), the present study reveals that brown algae have an acid detergent fiber content (consisting of cellulose and lignin) that is similar to that found in aquatic macrophytes and mangroves analyzed. Although it is below the value observed for submerged plants (marine angiosperms), the brown algae in this study may represent an important alternative for fiber supplementation, considering that diets poor in this nutrient can cause obesity, diabetes mellitus, gastric acidosis, inflammation, microbiota imbalance, poor digestion, thermoregulatory disorders, diarrhea, colic, and twisting or detachment of intestines in herbivorous mammals (SIEGAL-WILLOTT et al., 2010).

Among vascular plants, submerged plants are consumed in greater quantity (especially their rhizomes), followed by emerging and terrestrial plants, as well as floating plants (ALLEN et al., 2018). However, as the American manatee is an opportunistic and generalist herbivore, it is likely that mangrove consumption will be prioritized when there is low density of aquatic plants in the environment (CASTELBLANCO-MARTÍNEZ et al., 2012). Mangroves are used as shelter and their different parts are consumed by the American manatee, which is able to supplement its need for water by eating the leaves rich in fresh water (CASTELBLANCO-MARTÍNEZ et al., 2009; ALLEN et al., 2018). This richness was verified by the high average moisture content of the mangrove leaves (72.72%) presented in this study.

A few food items used by Antillean manatees in northeastern Brazil have undergone nutritional analysis, such as *Ulva lactuca*, *Amansia multifida*, *Hypnea musciformis* and *Gracilaria cervicornis* (RAMOS et al., 2000; WONG and CHEUNG, 2000; SILVA et al., 2002; MOTA DA SILVA et al., 2008; ARMAN and QUADER, 2012). However, only the dry matter

Table 2
Mean nutritional composition of foods consumed by Antillean manatees (*Trichechus manatus manatus*) in two periods of the year (rainy and dry).

Taxonomic group	Food item	Consumed part	Period of the year	DM (%)	CP (%)	NDF (%)	ADF (%)	MM (%)
Green algae	*Caulerpa cupressoides*	Whole	D	11.29	21.93	56.62	6.26	16.05
		Whole	R	n.a.	n.a.	n.a.	n.a.	n.a.
	Caulerpa mexicana	Whole	D	15.11*	18.78*	60.08	14.36	17.46*
		Whole	R	12.73*	21.10*	54.61	14.89	10.67*
	Caulerpa prolifera	Whole	D	17.64	20.17	56.59	19.15	14.50
		Whole	R	n.a.	n.a.	n.a.	n.a.	n.a.
	Caulerpa racemosa	Whole	D	6.61*	18.21	48.33*	4.75	15.72
		Whole	R	11.58*	19.44	59.69*	n.a.	n.a.
	Caulerpa sertularioides	Whole	D	14.07	21.29	57.43	21.07	14.23
		Whole	R	n.a.	n.a.	n.a.	n.a.	n.a.
	Ulva sp.	Whole	D	13.88*	10.78*	47.59*	18.50*	14.02*
		Whole	R	25.71*	5.35*	68.52*	57.39*	63.11*
Brown algae	*Dictyota mertensii*	Whole	D	12.85*	n.a.	n.a.	n.a.	n.a.
		Whole	R	14.79*	n.a.	43.41	22.62	n.a.
	Dictyopteris deliculata	Whole	D	12.11*	14.30*	40.21*	26.62*	25.50*
		Whole	R	13.50*	19.90*	31.16*	43.54*	29.76*
	Sargassum sp.1	Whole	D	15.65*	9.49*	48.72*	25.92*	28.74*
		Whole	R	13.80*	13.90*	37.74*	70.40*	17.38*
	Sargassum sp.2	Whole	D	n.a.	n.a.	n.a.	n.a.	n.a.
		Whole	R	16.48	20.06	60.68	21.45	29.65
Red algae	*Amansia multifida*	Whole	D	20.73*	13.58*	51.24*	10.71	31.47
		Whole	R	21.56*	20.73*	67.43*	16.36	29.83
	Cryptonemia crenulata	Whole	D	24.65*	19.03*	58.49	11.17	26.44*
		Whole	R	20.99*	19.73*	54.70	14.04	29.28*
Taxonomic group	**Food item**	**Consumed part**	**Period of the year**	**DM (%)**	**CP (%)**	**NDF (%)**	**ADF (%)**	**MM (%)**
Red algae	*Gracilaria caudata*	Whole	D	19.80*	14.90	45.09*	8.87*	7.46*
		Whole	R	17.66*	14.17	19.47*	8.89*	15.47*
	Gracilaria domingensis	Whole	D	14.98	13.64	26.15	4.32	17.35
		Whole	R	n.a.	n.a.	n.a.	n.a.	n.a.
	Gracilaria obtusata	Whole	D	16.95*	6.15*	35.04*	n.a.	61.92
		Whole	R	11.54*	6.52*	24.94*	21.24	65.37
	Gracilaria sp.1	Whole	D	25.15*	8.81	38.16	11.80*	57.70
		Whole	R	22.36*	8.78	31.53	41.89*	53.53
	Gracilaria sp.2	Whole	D	6.29*	13.93	14.72	7.12*	21.19
		Whole	R	17.70*	n.a.	n.a.	9.34*	n.a.
	Gracilaria sp.3	Whole	D	13.07*	15.92	35.88	11.35*	29.08
		Whole	R	17.70*	n.a.	n.a.	9.34*	n.a.
	Hypnea musciformis	Whole	D	11.94*	20.86*	26.86*	12.09	20.78*
		Whole	R	13.58*	29.55*	34.05*	8.49	16.37*
	Laurencia sp.	Whole	D	n.a.	n.a.	n.a.	n.a.	n.a.
		Whole	R	8.34	24.56	39.24	20.05	21.39
Aquatic macrophytes	*Blutaparon portulacoides*	Whole	D	15.89*	9.15*	37.25	16.57*	22.34
		Whole	R	21.83*	7.97*	48.96	23.24*	17.06
	Blutaparon portulacoides	Stem	D	20.28*	10.38*	n.a.	20.26*	17.56*
		Stem	R	24.83*	5.83*	n.a.	28.25*	13.19*
	Blutaparon portucaloides	Leaf	D	9.79*	13.55	24.48	11.85	29.72
		Leaf	R	23.84*	n.a.	n.a.	n.a.	n.a.
	Blutaparon portulacoides	Root	D	n.a.	n.a.	n.a.	n.a.	n.a.
		Root	R	36.64	6.49	48.68	25.75	11.81
	Eichhornia sp.	Whole	D	n.a.	n.a.	n.a.	n.a.	n.a.
		Whole	R	7.17	8.80	61.37	46.04	16.39
Taxonomic group	**Food item**	**Consumed part**	**Period of the year**	**DM (%)**	**CP (%)**	**NDF (%)**	**ADF (%)**	**MM (%)**
Aquatic macrophytes	*Eichhornia* sp.	Secondary Root	D	n.a.	n.a.	n.a.	n.a.	n.a.
		Secondary Root	R	8.25	n.a.	n.a.	n.a.	n.a.
	Eichhornia sp.	Leaf	D	n.a.	n.a.	n.a.	n.a.	n.a.
		Leaf	R	14.91	n.a.	n.a.	n.a.	n.a.
	Poacea	Whole	D	36.80*	5.47*	74.99*	35.34	11.51
		Whole	R	38.78*	5.75*	65.22*	35.78	14.62
	Poacea	Leaf	D	35.72*	6.55*	64.19*	34.13*	24.52*
		Leaf	R	41.51*	7.89*	78.26*	38.16*	7.71*
	Poacea	Root	D	45.38	6.92	69.28	33.50	11.24
		Root	R	n.a.	n.a.	n.a.	n.a.	n.a.
	Sesuvium portulacastrum	Stem	D	23.72*	5.33*	47.45*	22.20*	n.a.
		Stem	R	16.62*	6.38*	42.35*	26.12*	n.a.
	Sesuvium portulacastrum	Leaf	D	11.92*	7.78	21.67*	10.12*	37.65
		Leaf	R	11.07*	9.10	26.53*	15.52*	38.24
Mangroves	*Avicenia schaueriana*	Whole	D	30.88*	8.42*	38.15*	21.66*	13.88*
		Whole	R	23.09*	10.12*	34.46*	35.03*	13.28*
	Avicenia schaueriana	Stem	D	29.02*	7.07	46.52*	26.75	12.91
		Stem	R	33.94*	7.85	49.47*	29.24	13.69
	Avicenia schaueriana	Leaf	D	32.63*	8.86*	33.75	21.34*	12.59

(*continued on next page*)

Table 2 (*continued*)

Taxonomic group	Food item	Consumed part	Period of the year	DM (%)	CP (%)	NDF (%)	ADF (%)	MM (%)
		Leaf	R	24.59*	10.53*	34.09	35.74*	13.23
	Laguncularia racemosa	Whole	D	24.46*	6.58*	34.90	n.a.	15.71*
		Whole	R	22.19*	8.54*	35.81	n.a.	9.40*
	Laguncularia racemosa	Stem	D	30.68*	3.54	38.55	n.a.	11.06*
		Stem	R	28.63*	3.47	n.a.	37.52	10.31*
	Laguncularia racemosa	Leaf	D	24.09*	6.44*	34.27	15.94*	14.85*
		Leaf	R	23.21*	7.83*	34.80	45.71*	12.44*
Taxonomic group	**Food item**	**Consumed part**	**Period of the year**	**DM (%)**	**CP (%)**	**NDF (%)**	**ADF (%)**	**MM (%)**
	Laguncularia racemosa	Fluorescence	D	27.37	6.47	38.52	15.86	9.75
		Fluorescence	R	n.a.	n.a.	n.a.	n.a.	n.a.
	Rhizophora mangle	Whole	D	33.51*	6.21*	41.11	25.35*	10.13*
		Whole	R	25.79*	6.97*	40.02	42.16*	8.36*
Mangroves	*Rhizophora mangle*	Stem	D	26.85*	4.04	42.09*	23.91*	n.a.
		Stem	R	28.71*	3.70	53.79*	36.80*	n.a.
	Rhizophora mangle	Leaf	D	32.75*	6.55*	40.81	24.76*	8.93
		Leaf	R	26.46*	7.53*	40.05	53.10*	8.45
	Rhizophora mangle	Root	D	17.31*	2.86*	59.99*	41.79*	19.51*
		Root	R	16.38*	2.72*	57.05*	38.78*	21.74*
Marine angiosperms	*Halodule wrightii*	Whole	D	18.56*	12.82*	69.04	49.25*	14.00*
		Whole	R	16.66*	14.05*	67.04	39.39*	9.31*

D = Dry period; R = Rainy period; n.a. = Not available; DM = Dry Matter (%); CP = Crude Protein (%); NDF = Neutral Detergent Fiber (%); ADF = Acid Detergent Fiber (%); MM = Mineral Matter (%).
Means followed by *, at same the column, do significant difference between the dry and rainy periods (p < 0,005).

Table 3
Physico-chemical parameters of the water of the Mamanguape River in the rainy period of 2016 and dry period of 2017.

Physical-chemical parameter of the water	Estuary		Continental area	
	Feb/17	**Jul/16**	**Feb/17**	**Jul/16**
Turbidity (UTJ)	40 to 100	0 to 40	40 to 100	0 to 40
Dissolved oxygen (ppm)	4 to 6	0 to 4	4 to 6	0 to 4
Biochemical Oxygen Demand (ppm)	0 to 4	0 to 4	0 to 4	0 to 4
Hydrogen potential (pH)	5 to 9	5 to 9	7 to 9	5 to 9
Ammoniacal nitrogen (ppm)	< 5	< 5	5 to 20	< 5
Phosphate (ppm)	1 to 2	> 2	> 2	> 2
Temperature (°C)	31	27	32	27
Sedimentary material	Low	Low	Low	Low

of *U. lactuca* and *G. cervicornis* (16.00 and 17.86%, respectively) and the mineral matter of *H. musciformis* (15.30 to 22.43%) (MOTA DA SILVA et al., 2008; SILVA et al., 2002; ARMAN and QUADER, 2012) presented results similar to the genera addressed in the present study. Some species of the same taxonomic level consumed by Florida manatees and dugongs were analyzed. *Halodule uninervis* ingested by dugongs, for example, has a low fiber composition and high nitrogen (a constituent part of the protein) (D'Souza et al., 2015). The opposite was observed in the present study on *Halodule wrightii* and in other studies on the aquatic plants consumed by Florida manatees (SIEGAL-WILLOTT et al., 2010). As presented in this document, differences in the nutritional composition of different parts of aquatic plants have also been reported (ANDRÉ and LAWLER, 2003). Higher nitrogen values were found in the entire plant than in the leaves of *H. uninervis*, for example (ARAGONES et al., 2006). And higher levels of starch and dry matter were identified in the rhizomes, when compared to the leaves (SHEPPARD et al., 2007; SIEGAL-WILLOTT et al., 2010). The present study analyzed the *Halodule* genus without distinguishing between rhizomes and leaves, due to the priority of maintaining the biomass of the meadows of the study site that were low. However, low levels of protein are generally observed in aquatic plant roots when compared to the stem, leaf and whole plant. Higher values of this nutrient were found in *H. musciformis*, especially in the winter, which coincides with what was mentioned by the interviewed fishermen, that this is the most consumed food by the species after *H. wrightii* (rich in fiber).

According to observations made in meadows repeatedly frequented by the dugong (D'Souza et al., 2015), the nutritional composition of aquatic plants may vary with the frequency of consumption by herbivores (CASTELBLANCO-MARTÍNEZ et al., 2012). Studies with Amazonian manatees have also reported that the composition may vary according to the period of the year (Amazonian flood and drought periods) (GUTERRES-PAZIN et al., 2014). In the dry season, there is a decrease in food resources for American manatees in river and lagoon systems due to the reduction in water levels, limiting growth and altering the nutritional composition of aquatic plants, although it also favors the animals' access to the vegetation of the margins (SIEGAL-WILLOTT et al., 2010; PABLO-RODRÍGUEZ et al., 2016). In the present study, *Blutaparon portulacoides*, *Sesuvium portulacastrum* and *Rhizophora mangle* are located on the margins and may be an alternative for fiber intake during the fall of *H. wrightii* biomass, as they are rich in this nutrient (especially stems and roots). During the dry season in Florida, marine angiosperms lose biomass, but recover quickly in the rainy season, reducing the protein levels in the leaves and keeping the composition of rhizomes stable because they are anchoring structures little affected by photosynthetic stress (SIEGAL-WILLOTT et al., 2010). However, in the state of Paraíba, *H. wrightii* presented higher levels of protein in the rainy season, with the opposite occurring for the other nutrients.

The seasonal variation in the nutritional composition of these food items results from changes in water quality (light penetration, turbidity, salinity and temperature) that invoke changes in the availability of nutrients to add biomass or to combat stress (SIEGAL-WILLOTT et al., 2010). As with studies carried out with American manatees in Mexico (CASTELBLANCO-MARTÍNEZ et al., 2009), this study did not find an association between climatic and hydrological characteristics in the composition of the diet. However, in dugong feeding areas, studies observed that high salinity can reduce the richness of benthic algae, that *H. uninervis* is tolerant to sedimentation and that insolation and temperature influence leaf productivity more than rhizomes (MASINI et al., 2001). In the present study, the method used to measure WQI made it possible to classify the water in the Mamanguape River – according to resolution 357 of the National Environment Council of Brazil (Conama) – as "regular" in both collection points and periods of the year. This helped in the protection and development of the food items and nutritional components in a healthy environment. Considering these characteristics, food items that did not show a significant difference in nutritional composition between the dry and rainy periods can be appreciated by the American manatees throughout the year. The variation in the nutritional composition observed between this and other studies may be related to the geographical location and the methods of collecting, drying and washing the material, which can accumulate higher concentrations of salt, sand and water outside the plant.

This study may support new research on digestibility, digestive efficiency and nutritional requirements of Antillean manatees in Brazil, and assist in the development of basic maintenance diets for captive animals. Currently, it is known that American manatees have a slow digestive rhythm and efficient decomposition of fibrous material through microbial degradations (CASTELBLANCO-MARTÍNEZ et al., 2009), and that marine angiosperms have low lignin values, when compared with terrestrial angiosperms, allowing greater digestibility and less food consumption, when compared to terrestrial herbivores (GOTO et al., 2008; SIEGAL-WILLOTT et al., 2010). In dugongs, there is a direct correlation between fiber content and digestibility (WORTHY and WORTHY, 2014), presenting digestive efficiency of up to 84% when they consume marine angiosperms, differing from the Florida manatee which presents 47% efficiency (WORTHY and WORTHY, 2014). This means that Florida manatees need to feed on a greater biomass than dugongs to support their nutritional needs, requiring more time and effort in food acquisition (WORTHY and WORTHY, 2014).

Although there is a high fiber content in the *H. wrightii* found in Paraíba, the digestive efficiency of Antillean manatees in Brazil may be different due to changes in nutrient availability, sampling, analytical technique, sampling location, method calculation of energy content or changes in environmental parameters (water and soil quality, anthropogenic effects and others) (SIEGAL-WILLOTT et al., 2010). Due to the difficulties of studying free-ranging animals, data on nutritional and energy needs are often lacking, and may vary depending on body size, activity level, reproductive status and thermoregulatory cost (GOTO et al., 2008). Studies with American manatees can advance by combining daily rates of food intake with energy needs, digestive efficiency and nutritional and energetic compositions of potential foods (WORTHY and WORTHY, 2014). Therefore, the composition of the food items presented is an indicator for the animal's performance, although limited to conclude about all the nutritional aspects of the species (ARAGONES et al., 2006).

The nutritional composition of 31 food items of the Antillean manatee diet in Brazil was identified, including green, brown, and red algae, aquatic macrophytes, mangroves and marine angiosperms. Among the preferred foods on the coast of Paraíba are *H. wrightii* and *H. musciformis*, which are characterized by the highest levels of fiber and protein in the study. When *H. wrightii* biomass falls during the dry season, brown algae, *B. portulacoides*, *S. portulacastrum* and *R. mangle* can be an alternative to fiber intake, since they are rich in this nutrient and appreciated by Antillean manatees. This information can contribute for Antillean manatee management during rehabilitation, considering the need to formulate diets similar to that found in nature and with nutritional values able to develop a healthy and fit animal to fetch its food after release.

CRediT authorship contribution statement

Fernanda M. Rodrigues: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing - original draft. **Anna Karolina V. Marin:** Methodology. **Vanessa A. Rebelo:** Methodology. **Miriam Marmontel:** Conceptualization, Writing - review & editing, Visualization. **João Carlos G. Borges:** Conceptualization, Methodology, Validation, Resources, Writing - review & editing, Visualization, Funding acquisition. **Jociery E. Vergara-Parente:** Conceptualization, Validation, Resources, Writing - review & editing. **Eliane S. Miyagi:** Conceptualization, Validation, Resources, Writing - review & editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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