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Diet of the manatees (*Trichechus manatus manatus*) in Chetumal Bay, Mexico[1]

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Abstract: Manatees, as well as other sirenians, are aquatic, opportunistic herbivores. Knowledge of their diet is important to determine habitat requirements. This is the first study of manatee diet in México. Our main objective was to identify the plant species eaten by manatees in Chetumal Bay, and to establish if diet composition varied by climatic season, sex or age class. We compared plant epidermal fragments found in feces with histological descriptions and permanent collections of suspected plants and algae. Thirty-six fecal samples and nine tract digestive content samples (mouth, stomach, and cecum) were examined. We found eight distinct plant items, including seagrasses, freshwater grasses, algae and vascular plants. *Halodule wrightii* and *Thalassia testudinum* were found in 41 samples (92%), and *Ruppia* sp. was present in 57.8%. Another common item was red mangrove (*Rhizophora mangle*), found in 66.7% of samples. Additionally, we report *Chara* sp. and *Najas* sp. as part of the West Indian manatee's diet outside of Florida. A multivariate analysis based on a presence/absence triangular matrix and a similarity analysis were used to test differences among samples. Season, sex or age class did not influence diet composition. All species identified are present in Chetumal Bay, suggesting that manatees do not move long distances at sea in search of food. We postulate that consumption of red mangrove by Chetumal Bay manatees may occur as compensation for the scarcity of submersed aquatic plants, which has not been reported for other habitats for this species.

Resumen: Los manatíes, así como los demás miembros del orden Sirenia, son herbívoros acuáticos oportunistas. El conocimiento de su dieta es importante para determinar requerimientos de su hábitat. Este es el primer estudio sobre la dieta del manatí en México. El objetivo principal fue identificar las especies vegetales consumidas por manatíes en Bahía de Chetumal, y establecer si la composición de la dieta varía según la estación climática, sexo o clase etaria. Comparamos los fragmentos vegetales encontrados en heces con las descripciones histológicas y colecciones permanentes de especies vegetales probables. Examinamos 36 muestras fecales y nueve contenidos del tracto digestivo (boca, estómago y ciego). Encontramos ocho ítems vegetales, incluyendo pastos marinos, pastos de agua dulce, algas y plantas vasculares. *Halodule wrightii* y *Thalassia testudinum* se encontraron en 41 muestras (92%), y *Ruppia* sp. se presentó en 57.8%. Otro ítem común fue el mangle rojo (*Rhizophora mangle*), encontrado en el 66.7% de las muestras. Adicionalmente se reportan *Chara* sp. y *Najas* sp. como parte de la dieta del manatí de las Indias Occidentales fuera de la Florida. Se usó un análisis multivariado basado en una matriz triangular de presencia/ausencia, así como un análisis de similitud para probar diferencias entre muestras. La estación climática, sexo y clase etaria no influyeron en la composición de la dieta. Todas las especies identificadas se encuentran en la Bahía de Chetumal, mostrando que los manatíes no necesitan desplazarse fuera de ella en busca de alimento. Los resultados permiten asumir que el mangle es un ítem alimenticio importante para la población de manatíes en la Bahía de Chetumal, como compensación a la escasez de plantas acuáticas sumergidas. Esto no ha sido informado para otros hábitats usados por la especie.

Keywords: herbivory, food, feeding habits, Caribbean Sea, microhistological analysis.

Introduction

The West Indian manatee (*Trichechus manatus*), along with related sirenian species, is the only herbivorous aquatic mammal that feeds on a variety of aquatic and semi-aquatic vegetation. Adult specimens are able to ingest 4-9% of their body weight daily (Bengtson, 1983; Etheridge *et al.*, 1985). Compared to other herbivorous mammals, the manatee is highly efficient at digesting cellulose (Lomolino and Ewel, 1984; Burn, 1986). Some relevant morphological and physiological adaptations, related to its feeding habits, are the unusually large degree of fine motor control of the snout and perioral bristles (Ronald *et al.*, 1978; Marshall *et al.*, 1998; Marshall *et al.*, 2000; Marshall *et al.*, 2003), horizontal tooth replacement (Domning, 1983), and specialized hind-gut fermentation in a large cecum located at the juncture of the large and small intestines (Best, 1981; Burn and Odell, 1987).

Chetumal Bay has been declared a Manatee Protected Area since 1996, and is part of a wider region in the Caribbean, where *T. manatus* occurs in high abundance (O'Shea and Salisbury, 1991; Morales-Vela and Olivera-Gómez, 1994; Morales-Vela, 1997). Some characteristics of Chetumal Bay that favor the occurrence of manatees are protection against wind and currents, availability of freshwater, large shallow areas with submerged and riparian vegetation, and sparse human activity.

There is an important geographical variation in the foraging strategies of manatees, as shown by its diet composition (Reich and Worthy, 2006), due to its wide distribution and large variety of habitats where the manatee occurs (Lefebvre *et al.*, 2001). Information on feeding behavior and diet composition are key aspects for local and regional manatee conservation strategies.

Analysis of fecal and digestive contents is a simple, inexpensive and reliable procedure for determining feeding habits of herbivores (Fitzgerald and Waddington, 1979; Garin *et al.*, 2001; Sepúlveda-Palma *et al.*, 2004; Borges and Colares, 2007). The technique has

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been used for studying feeding habits of other species of sirenians (Heinsohn and Birch, 1972; Johnstone and Hudston, 1981; Marsh *et al.*, 1982; Ledder, 1986; Hurst and Beck, 1988; Colares and Colares, 2002; Adulyanukosol *et al.*, 2004; Guterres *et al.*, 2008), however, the diet composition of the subspecies *T. m. manatus* has received relatively little attention (Mignucci-Giannoni and Beck, 1998; Borges *et al.*, 2008).

In this study, we analyze fecal and gut contents of manatees from Chetumal Bay to determine diet composition and plant selection by season, sex and age-class.

Methods

Study area

Chetumal Bay (17º52'-18º50'N, 87º50'-88º25'W), is a large shallow estuary of ~2450km^2 with an average depth of 3.2m, shared by Mexico and Belize. This coastal system of karstic origin and low productivity has variable marine influence, permanent freshwater inputs through the Rio Hondo, New River, and continuous underground runoff (Carrillo *et al.*, 2009; Castellanos-Osorio, 2009). Intra-annual climatic variability is driven by dry, rainy and cold front seasons with occurrence of tropical storms and hurricanes in a larger temporal scale (Carrillo *et al.*, 2009). Submerged vegetation is formed by *Thalassia testudinum*, *Halodule wrightii*, *Ruppia* sp., *Najas* sp., several macroalgae species (Quan-Young *et al.*, 2006) and four species of mangroves (*Rhizophora mangl*e, *Laguncularia racemosa*, *Conocarpus erectus* and *Avicennia germinans*).

Microhistological analyses

One useful technique to determine diet is based on direct comparison of plant fragments present in feces and gut contents with voucher slide specimens or illustrations in reference collections (Hurst and Beck, 1988; Rosito and Marchezan, 2003). We obtained samples from wild manatees that had been captured for health monitoring, from dead animals during necropsies, or from opportunistic collection of feces found floating in the bay (Opportunistic samples are denoted as ¨unknown¨ in Table 1). All samples were preserved in FAA (85% ethyl alcohol, 10% formalin at 10%, 5% glacial acetic acid) (Colares, 1990).

Samples were collected from 2004 to 2007, and included 36 fecal samples and nine from gut content samples (one collected from the cecum, two from the stomach, and six from the mouth) (Table 1). Each sample was homogenized and filtered through a 425µm sieve. A subsample from the material retained on the sieve was placed in a Petri dish, cleared with 20 drops of sodium hypoclorite to help microstructure observation of plant debris. An aliquot was placed on a glass slide with a grid of 36 fields. Five glass slides were observed under the microscope at 10X, 40X and, if necessary, 100X magnification. For each field of the glass slide the plant fragments were identified up to species level using the guides proposed by Hurst and Beck (1988) and Orozco-Meyer (1995) and a reference collection of plant tissues from Chetumal Bay. Species identification was made considering size and shape of epidermal cells, presence and distribution of tannin and silica deposits, distribution and types of stomata, and distribution, types and sizes of trichomes and veins (Heinsohn and Birch, 1972; Colares and Colares, 2002). All mouth content samples were observed under a stereoscopic microscope. Key aspects for plant species identification were the leaf apex, enervation, hardness, edge ornaments, and the size, shape and arrangement of epidermal cells (Johnstone and Hudston, 1981).

Data analysis

The analysis was designed a priori in order to evaluate differences in diet composition related to sex, age and season. Manatees ≤175cm were considered calves that were nutritionally dependent on females (O'Shea *et al.*, 1985), while the rest of the organisms individuals were treated as adults. A multivariate statistical Analysis of Similarity (ANOSIM), based on a presence/absence triangular similarity matrix of plant items was used to test for differences against and among different levels of main factors (sex, age and season). A Bray-Curtis index of similarity was used to construct the triangular matrix and a graphical interface by means of non-metric MDS was used to show any patterns of similarity in the data (Clarke and Warwick, 1994).

Results

Eight plant items were recorded overall, of which four were identified to species level, two to genus level and the other two named as species 1 and species 2. Grass rhizome was found in all samples. However, identification to the genus or species level was not possible and we therefore excluded this item from the analysis. The numbers of plant items found per sample ranged from two to seven, but three to four items were predominant in most samples (Figure 1). Mouth samples only contained one or two plant species. Stomach samples contained three to five species, whereas in cecum samples, four species were identified.

The manatee diet from Chetumal Bay was mainly composed of phanerogams (Table 2). Seagrasses, such as *Halodule wrightii* and *Thalassia testudinum,* were present in 91% of the samples, whereas *Ruppia* sp. was present in 58% of the samples. We found typical leaf tissue and H-shaped trichosclereids of *Rhizophora mangle* in 30 fecal samples, but none in digestive content samples. *Chara* sp. was present in two stomach samples, but only in 11% of the fecal samples. *Najas* sp. was present in 9% of the samples including feces, stomach and cecum contents. Two unidentified plant species were recorded, (species 1 and 2) in 24% and 16% of samples, respectively. Statistical analyses showed that there were no effects on diet composition related to season, sex or age class.

Table 1. Fecal and digestive content samples used for diet determination of manatees in Chetumal Bay.

SAMPLE ID	MANATEE ID	INDIVIDUAL STATE	TYPE	DATE	SEASON	SEX	LENGTH (cm)	AGE CLASS
1	BCH01	Alive	Fecal	24/05/2004	Dry	♀	275	Adult
2	BCH02	Alive	Fecal	25/05/2004	Dry	♀	225	Adult
3	BCH04	Alive	Fecal	25/05/2004	Dry	♀	283	Adult
4	BCH06	Alive	Fecal	28/05/2004	Dry	♂	227	Adult
5	BCH07	Alive	Fecal	28/05/2004	Dry	♀	275	Adult
6	BCH12	Alive	Fecal	03/10/2004	Cold Fronts	♀	298	Adult
7	BCH13	Alive	Fecal	04/10/2004	Cold Fronts	♂	270	Adult
8	BCH16	Alive	Fecal	12/10/2004	Cold Fronts	♀	283	Adult
9	BCH30	Alive	Fecal	08/09/2005	Rainy	♀	253	Adult
10	BCH32	Alive	Fecal	25/10/2005	Rainy	♂	206	Adult
11	BCH34	Alive	Fecal	26/03/2006	Dry	♂	165	Calf
12	BCH35	Alive	Fecal	26/06/2006	Rainy	♂	267	Adult
13	BCH36	Alive	Fecal	27/06/2006	Rainy	♂	292	Adult
14	BCH37	Alive	Fecal	28/03/2006	Dry	♀	196	Calf
15	BCH38	Alive	Fecal	29/03/2006	Dry	♂	228	Adult
16	BCH40	Alive	Fecal	11/10/2006	Rainy	♀	268	Adult
17	BCH41	Alive	Fecal	12/10/2006	Rainy	♂	233	Adult
18	BCH42	Alive	Fecal	13/10/2006	Rainy	♀	286	Adult
19	BCH43	Alive	Fecal	14/05/2006	Dry	♂	282	Adult
20	BCH46	Alive	Fecal	19/03/2007	Dry	♀	280	Adult
21	BCH47	Alive	Fecal	20/03/2007	Dry	♂	304	Adult
22	BCH48	Alive	Fecal	22/03/2007	Dry	♂	268	Adult
23	BCH49	Alive	Fecal	22/03/2007	Dry	♂	250	Adult
24	BCH50	Alive	Fecal	23/03/2007	Dry	♀	177	Calf
25	BCH52	Alive	Fecal	18/05/2007	Dry	♀	312	Adult
26	BCH53	Alive	Fecal	24/05/2007	Dry	♀	285	Adult
27	TQR02	Alive	Fecal	17/11/1994	Cold Fronts	---	---	Adult
28	---	Unknown	Fecal	06/02/1995	Cold Fronts	---	---	Adult
29	---	Unknown	Fecal	20/02/1995	Cold Fronts	---	---	---
30	---	Unknown	Fecal	20/02/1995	Cold Fronts	---	---	---
31	---	Alive	Fecal	03/05/1995	Dry	---	---	---
32	---	Unknown	Fecal	05/1998	Dry	---	---	---
33	---	Unknown	Fecal	02/09/1995	Rainy	---	---	---
34	---	Unknown	Fecal	20/10/1998	Cold Fronts	---	---	---
35	---	Unknown	Fecal	23/04/2000	Dry	---	---	---
36	BCH52	Alive	Fecal	13/02/2001	Cold Fronts	♂	---	Calf
37	---	Death	Cecum	11/03/2002	Dry	♂	282	Adult
38	---	Death	Stomach	30/01/2001	Cold Fronts	♀	158	Calf
39	---	Death	Stomach	02/2004	Cold Fronts	♀	---	---
40	---	Death	Mouth	18/05/2007	Dry	♀	312	Adult
41	---	Alive	Mouth	29/04/2004	Dry	♂	---	Adult
42	BCH02	Alive	Mouth	25/05/2004	Dry	♀	225	Adult
43	---	Alive	Mouth	05/05/2004	Dry	---	---	---
44	BCH07	Alive	Mouth	28/05/2004	Dry	♀	275	Adult
45	BCH06	Alive	Mouth	28/05/2004	Dry	♂	227	Adult

Discussion

Although determination of mouth contents is a relatively easy task, only two plant species were identified in mouth content samples because manatees tend to graze in submerged beds of dominant seagrasses (Campbell and Irvine, 1977; Hartman, 1979; Packard, 1984; Lefebvre and Powell, 1990; Provancha and Hall, 1991) similar to dugongs (Johnstone and Hudston, 1981). Manatee digestive passage times range from four to ten days (Larkin *et al.*, 2007), therefore, fecal material is likely to reflect weekly individual feeding habits. In accordance with this idea, and in contrast to what was observed in mouth, stomach and cecum contents, fecal samples contained all of the listed species. The number of listed species is in correspondence with the general diversity of submerged vegetation in Chetumal Bay (Espinoza-Avalos, 1996), thus we consider our sample size 'representative' and the histological analyses adequate for preliminary identification of the diet composition of manatees in Chetumal Bay.

The study of herbivorous diet using histological analyses of feces does not allow the determination of the relevance of each item, since each plant undergoes a particular digestive process depending on its physical and chemical features (Fitzgerald and Waddington, 1979). Thus, depending on the plant´s resistance to digestion, the

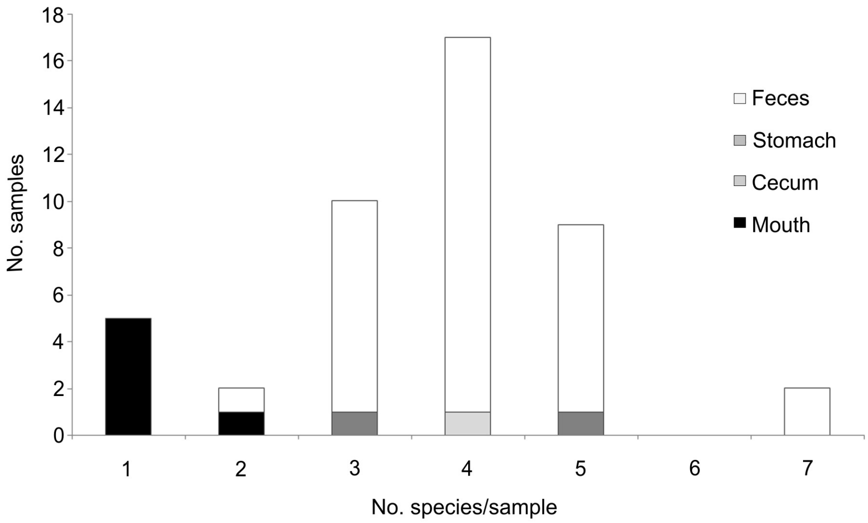

Figure 1. Richness of plant species found in fecal and digestive content samples of manatees from Chetumal Bay

Table 2. Number and percentage of diet items of manatees from Chetumal Bay.

	Tt	*Hw*	*Rhm*	*Rum*	Species 1	Species 2	*Ch*	*N*
Feces (36)	36	35	30	22	11	7	4	2
Cecum (1)	1	1	0	1	0	0	0	1
Stomach (2)	2	1	0	2	0	0	2	1
Mouth (6)	2	4	0	1	0	0	0	0
Total (45)	41	41	30	26	11	7	6	4
Percent (%)	91.1	91.1	66.7	57.8	24.4	15.6	13.3	8.9

Tt= *Thalassia testudinum*, *Hw*= *Halodule wrightii*, *Rhm*= *Rhizophora mangle*, *Rum*= *Ruppia maritima*, *Ch*= *Chara* sp., *N*= *Najas* sp. Fragments of seagrass rhizomes are not included as they were found in all samples. The number of samples is indicated in brackets.

amount of plant fragments in feces would vary leading to an underestimation of less resistant species, such as algae (Garin *et al.*, 2001); therefore, quantitative comparisons between items is not reliable.

The number of items per sample ranged between one and seven, similar to what has been found in other studies using the same technique: 2-8 for *Trichechus manatus manatus* in Puerto Rico (Mignucci-Giannoni and Beck, 1998), 2-9 for *T. m. m.* in Brazil (Borges et al., 2008), 2-10 for *T. m. latirostris* in Florida (Ledder, 1986), 1-7 for *T. inunguis* (Colares and Colares, 2002), and 1-5 for *Dugong dugon* (Heinsohn and Birch, 1972).

Mignucci-Giannoni and Beck (1998) recorded eight plant species in the gut content of manatees from Puerto Rico. Species common between our study and this previous one were *Thalassia testudinum*, *Halodule wrightii* and *Rhizophora mangle*. Additionally, for the manatee from Puerto Rico, *Syringodium filiforme*, *Ulva lactuca* and *Caulerpa prolifera* were also recorded (Mignucci-Giannoni and Beck, 1998). Those three species, although present in the neighboring reef lagoon, have not been found in the estuarine system of Chetumal Bay (Espinoza-Avalos, 1996). Studies in northeastern Brazil have reported up to 21 plant items, including phanerogams, green, red and brown algae in gut content of manatees, despite a smaller sample size (Borges *et al.*, 2008). This result clearly reflects the greater diversity of habitats and plant species available for manatees on the Brazilian coast. A large variety of food items have been reported also for sirenians inhabiting high biodiversity areas, such as dugong (Marsh *et al.*, 1982) and Amazonian manatee (Colares and Colares, 2002). From the 25 plant species recorded as food items for the Caribbean manatee, only *H. wrightii* and *R. mangle* were common to Puerto Rico, Brazil and México (Table 3).

As found in other studies (Ledder, 1986; Mignucci-Giannoni and Beck, 1998) seagrasses were the plant most frequently consumed by manatees in Chetumal Bay. Algae species such as *Batophora* sp. and *Chara* sp, are common in Chetumal Bay and in the channel system of Laguna Guerrero, and are a potentially important food resource for manatees. Also, manatees have been observed consuming *Batophora* sp. However, only *Chara* sp. was found in low proportion in our content samples. Algae consumption by manatees has been widely documented (Lewis *et al.*, 1984; Mignucci-Giannoni and Beck, 1998; Borges *et al.*, 2008), but it seems to be an incidental ingestion (Reynolds III and Rommel, 1996) and apparently algae is not a significant part of the manatees' diet (Snipes, 1984). Manatees have a slow digestive rate and efficient breakdown of fibrous plant material (Reynolds III and Rommel, 1996) by means of microbial degradations (Snipes, 1984). As a selective feeder, they might prefer to feed on vascular plants that are rich in cellulose.

It is known that manatees consume mangroves. In our study, mangrove was recorded in 68% of the analyzed samples, whereas it was found in two of eight stomach samples from Puerto Rico (Mignucci-Giannoni and Beck, 1998). In northeastern Brazil, mangrove was reported in 23% of the analyzed samples (Borges *et al.*, 2008).

Sirenians are generalist herbivores feeding on submerged vegetation in a variety of environments and depths. They are also opportunistic feeders because they consume vegetation with the highest spatial cover within the inhabited area (Heinsohn and Birch, 1972; Domning, 1980; Johnstone and Hudston, 1981; Marsh *et al.*, 1982;

Table 3. Diet composition of *Trichechus manatus manatus*, determined by histological analysis in Puerto Rico (Mignucci-Giannoni and Beck, 1998), Brazil (Borges *et al.*, 2008) and Chetumal Bay, México.

					PUERTO RICO	BRAZIL	MEXICO
				SAMPLE TYPE	STOMACH CONTENTS	STOMACH CONTENTS AND FECES	STOMACH, MOUTH AND CECUM CONTENTS AND FECES
				Nº SAMPLES	8	23	45
PHYLUM	CLASS	ORDER	FAMILY	SPECIES			
Tracheophyta (Phanerogams)	Magnoliopsida	Alismatales	Cymodoceaceae	*Halodule wrightii*	+	+	+
				Syringodium filiforme	+		
		Alismatales	Hydrocharitaceae	*Halophila* sp.		+	
				Najas sp.			+
				Thalassia testudinum	+		+
		Alismatales	Ruppiaceae	*Ruppia maritima*			+
		Malpighiales	Rhizophoraceae	*Rhizophora mangle*	+*	+*	+
Rhodophyta (Red algae)	Florideophyceae	Ceramiales	Rhodomelaceae	*Bryothamnion seaforthii*		+	
				Osmundaria obtusiloba		+	
		Cryptonemiales	Halymeniaceae	*Cryptonemia crenulata*		+	
		Gelidiales	Gelidiaceae	*Gelidium* sp.		+	
		Gelidiales	Gelidiellaceae	*Gelidiella acerosa*		+	
		Gigartinales	Hypneaceae	*Hypnea musciformis*		+	
		Gracilariales	Gracilariaceae	*Gracilaria* sp.		+	
Chlorophyta (Green algae)	Bryopsidophyceae	Bryopsidales	Caulerpaceae	*Caulerpa cupressoides*		+	
				Caulerpa mexicana		+	
				Caulerpa prolifera	+	+	
				Caulerpa sertularioides		+	
	Ulvophyceae	Cladophorales	Anadyomenaceae	*Anadyomene stellata*		+	
		Ulvales	Ulvaceae	*Ulva lactuca*	+		
Charophyta (Brown algae)	Charophyceae	Charales	Characeae	*Chara* sp.			+
	Phaeophyceae	Dyctyotales	Dictyotaceae	*Dictyopteris* sp.		+	
				Dictyota sp.		+	
				Padina gymnospora		+	
		Fucales	Sargassaceae	*Sargassum* sp.		+	

(*) Authors report 'mangrove' but did not specify the species.

Ledder, 1986; Mignucci-Giannoni and Beck, 1998; Borges *et al.*, 2008). Seagrass biomass in Chetumal Bay is low compared to other systems where this species occurs (Espinoza-Avalos *et al.*, 2009). Additionally, the number of macroalgae in Chetumal Bay is low, reflecting that this system is relatively poor in submerged vegetation (Quan-Young *et al.*, 2006). Thus, our results suggest that mangroves are a food supply for the local population of manatees. H-shaped, brilliant idioblasts were found in fecal samples from Chetumal Bay. This kind of structures are especially abundant in aerial roots and seedling hypocotyls of red mangrove (Tomlinson and Cox, 2000). Also, fragments of mangrove leaves tissue were registered. This suggests than manatees explore different parts of mangrove plants.

All the plant species recorded in this study are distributed within Chetumal Bay (Espinoza-Avalos, 1996). The absence of strict marine plants (i.e. *Siryngodium* sp.) in the manatees' diet might suggest that the local population of Chetumal Bay do not travel out to sea to feed, in contrast to what Reich and Worthy (2006) reported for the Florida manatee, which consumes mainly estuarine and marine grasses and algae.

This study did not find an association between climate or season and diet composition, similar to what Preen (1995) reported for dugong. However, Amazonian manatees are known to modify their diet throughout the year in response to changes in water levels which control the amount and type of vegetation available (Best, 1983; Colares *et al.*, 2000). It appears that the Chetumal Bay manatee population's feeding habits are not influenced by yearly variations in submerged vegetation growth and availability.

Seagrasses, freshwater grasses and mangrove areas are threatened by both natural phenomena and human-related activities. Aquatic grasses, the main component of manatee's diet, are widely distributed but scarce in Chetumal Bay. This is probably due to local substrate instability, which reduces the light penetration and limits the seagrasses beds proliferation (Espinoza-Avalos *et al.*, 2009). Storm-water runoff and hurricanes can have huge consequences for the longterm persistence of the mangroves and seagrasses communities (Mangel and Tier, 1994). These phenomena also have a relevant effect on the bottom structure and therefore, on plant community's composition. Stochastic events, especially if severe or frequent, are a source of direct and indirect mortality of sirenians (Spain and Heinsohn, 1973; Heinsohn and Spain, 1974; Marsh *et al.*, 1986; Marsh, 1989; Preen and Marsh, 1995; Langtimm and Beck, 2003; Gales *et al.*, 2004; Langtimm *et al.*, 2006). If the food base is degraded or destroyed, manatees could change their feeding habits (Spain and Heinsohn, 1973) or voluntarily leave, as has been documented with dugongs (Heinsohn and Spain, 1974; Preen and Marsh, 1995). Mortality and emigration evidently have important implications for the recovery and persistence of the local manatee population (Langtimm *et al.*, 2006).

At the other hand, development of coastal areas for residential and commercial purposes, upland agricultural activities, increased wastewater discharge, chemical contamination and aquatic recreational and commercial activities decrease water quality and lead to a reduction in the available foraging habitat for manatees (Smith, 1993). In Chetumal Bay, minimization of human-related threats to aquatic and sub-aquatic vegetation should be a priority for the permanence of the manatee population.

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