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Gastrointestinal Parasites and Food Intake of Stranded Juvenile Green Turtles *Chelonia mydas* (Testudines: Cheloniidae) in Rio de Janeiro, Brazil

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Abstract

Chelonia mydas can be found worldwide, mainly in coastal habitats ranging from tropical regions to temperate zones. They usually consume a diverse range of food types, however, adults are considered one of the most abundant large vertebrate consumers of seagrasses and algae in the world. Anthropogenic activities can affect C. mydas morbidity, mortality and food intake pattern. The aim of this study was to evaluate if parasites can interfere with the food intake of green turtles in Rio de Janeiro, Brazil, after gastrointestinal content and parasitological analysis. A total of 137 stranded green sea turtles were analyzed, according to the presence of parasites and the digestive tract content: 12% presented parasite infection. The most frequent item among the digestive tract content was algae (74%), followed by anthropogenic materials (19.8%), invertebrates (5.8%) and plants (0.4%). The algae mostly ingested were the Chlorophyta with 36,16% and Rhodophyta with 27,68%. Phaeophyta represented 14,69% of the consumed algae, 20,9% of the algae could not be identified due to the digestive process. Thus, in this study we could observe a change in species composition and algal frequency in green turtles with or without parasites. Hypnea sp. is frequently reported in the literature as part of the diet of C. mydas and, the same was observed in our results in non-parasitized green turtles. More studies are necessary to better understand anthropogenic debris and parasites infection effects on food intake of stranded juvenile green turtles *Chelonia mydas*.

Keywords: parasites; Infection; diet shift; sea turtle; Atlantic ocean.

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1. Introduction

Food intake may change under several ecological contexts [1]. Changes in availability of feeding resources might influence the animal's choice [2, 3], as well as ontogeny might also cause changes in nutritional demand [4], migration season usually requires a more caloric food intake [5] and parasites might also drive food selection according to nutritional deficiency [6]. Some aquatic species have already been described to shift their food intake according to parasitic infection [7].

The green turtle (*Chelonia mydas*) can be found worldwide, mainly in coastal habitats ranging from tropical regions to temperate zones [8]. With the exception of migration for breeding, turtles usually remain in benthic inshore waters at the age of 3-5 years and are commonly associated with coral reefs or seagrass meadows. They usually consume a diverse range of food types, however, adults are considered one of the most abundant large vertebrate consumers of seagrasses and algae in the world [9, 10]. Juvenile turtles are primarily omnivorous, feeding on a range of planktonic material including crustaceans, jellyfish and ctenophores [11, 12].

Anthropogenic activities can affect *C. mydas* morbidity, mortality and food intake. These factors are related to: boat collisions; overexploitation of eggs and adult females during nesting, capture of males; marine debris intake, such as plastics, fishing line and rope; habitat degradation including environmental contamination and dissemination of pathological agents from domestic, agricultural and industrial run-offs [13, 16] . Parasitic infections of endangered wild animals such as green turtles have drawn attention due to large influence in a whole population, affecting host survival as well as reproduction age [17].

Due to sea turtles migratory habits, gastrointestinal parasites are considered one of the most adapted organisms to marine environments as well as their host [18]. Usually, helminths are the main group of parasites detected on *C. mydas* carcasses along the Brazilian coast [19, 22].

The aim of this study was to evaluate if parasites can interfere with the food intake of green turtles in Rio de Janeiro, Brazil, after gastrointestinal content and parasitological analysis.

2. Material and Methods

All data was analyzed based on the Aquatic Biota Monitoring Information System platform – SIMBA – Petrobras. These data were collected by the Beach Monitoring Program (Programa de Monitoramento de Praias da Bacia de Santos – PMP-BS) along the Santos Basin, Rio de Janeiro, Brazil, and stored in SIMBA platform for public domain and access. We screened data according to the following information: 1) Occurrence of stranded green sea turtle *C. mydas*; 2) intestinal parasites/parasites analysis from green sea turtle *C. mydas*; and 3) stomach content analysis from the green sea turtle *C. mydas*.

Only juvenile green sea turtles were taken into consideration. Parasites were classified as endo and ectoparasites; while stomach content was considered according to species (when it was described so) or major classification (phylum, division).

Simple linear correlation was performed to identify dietary shift between sea turtles with parasite infection and without parasite infection. A reference list of all foraging items found in samples, their frequency of occurrence (i.e., the number of samples a foraging item was present in), and their average percent composition (±SD) in samples was constructed. Statistical analyses (PERMANOVA, DISTLM) were made using PRIMER (version 6) + PERMANOVA software. Pairwise comparisons were used, when appropriate, to resolve differences among levels of significant factors ($p < 0.05$).

3. Results

A total of 137 stranded green sea turtles were analyzed, according to the presence of parasites and the digestive tract content. Only 12% (n=17) of them had parasitic infection, among ectoparasites, endoparasites, cysts and eggs and 2% (n=3) had only non-identified digested content.

Among the digestive tract content of the green sea turtle (n=134), which was possible to identify, the most frequent item was algae (74%), followed by anthropogenic materials (19.8%), invertebrates (5.8%) and plants (0.4%) (Table 1). The algae mostly ingested were the Chlorophyta with 36,16% and Rhodophyta with 27,68%. Phaeophyta represented 14,69% of the consumed algae, 20,9% of the algae could not be identified due to the digestive process and 0,57% was represented by plant fragments.

Considering the most representative items, basically algae, data suggested a dietary shift between sea turtles with parasite infection and without parasite infection (Correl -0,00639). Sea turtles with parasite infection ingested mostly Clorophyta and Rodophyta and significantly less Phaeophyta (PERMANOVA, F=2,1612, p<0,001). However, turtles without parasite infection consumed mostly Clorophyta followed by significantly less consumption of Rodophyta and Phaeophyta (PERMANOVA, F=5,1414, p<0,05) (Figure 1 A).

Samples contained over 26 macroalgae taxon and 20 non-algal food items (e.g., clothing tissue, synthetic sponge, invertebrates, etc) (Table 1). Of the total number of algae found, only 12 taxa were present in turtles with parasites. The three species of algae *Hypnea* sp., *Gracilaria* sp., *Pterocladiella* sp. together corresponded to 50% of the total frequency of rhodophytes found in the intestinal tract of all turtles (10.5%).

The algae *Ulva* sp. was the most frequent chlorophyte, corresponding to 10.92%, and among the phaeophytes, *Sargassum* sp. had a frequency of 7.56% (Table 1). *Hypnea* sp. was not found in turtles with parasites, and the most consumed algae by them were *Ulva* sp. and *Pterocladiella* sp., corresponding together to 3.42% of the total frequency of algae present in the intestinal tract of these turtles (Figure 1B). While turtles without parasites frequently consumed *Ulva* sp. (9.83%), *Sargassum* sp. (7.26%), *Hypnea* sp. (3.42%) and *Gracilaria* sp. (2.99%).

Sea turtles with parasite infection did not ingest animals and considering anthropogenic materials consumption, 17.6% of the infected sea turtles consumed solid trash, while 24% of the non infected sea turtles ingested it. No significant difference has been identified between both consumption ($p=0.385, \chi2=0.753$), suggesting that parasite infection has no influence on trash ingestion (Figure 1).

Table 1: Foraging items present in the digestive tract of green sea turtle *Chelonia mydas* in Rio de Janeiro state (n=137).

Digestive tract items					
Taxons	**Frequency**	**Frequency % of total items found in the intestinal tract**	**Frequency ±SD**	**Taxa on turtles with or without parasites**	**Frequency %**
RODOPHYTA	15	6.30	0.31	**WITH PARASITES**	
Gelidiaceae	2	0.84	0.12	**INFECTION**	0,43
Gelidium sp.	1	0.42	0.09	*G. floridanum*	0,43
G. floridanum W.R. Taylor	3	1.26	0.15	Halymeniaceae	0,85
Hypnea sp.	8	3.36	0.24	*Gracilaria* sp.	2,14
Halymeniaceae	1	0.42	0.09	*Pterocladiella* sp.	0,43
Kappaphycus alvarezii	2	0.84	0.12	*Colpomenia* sp.	0,43
(Doty) L.M. Liao				*Chaetomorpha antennina*	0,43
Gracilariaceae	1	0.42	0.09	*Codium* sp.	1,28
Gracilaria sp.	9	3.78	0.25	*Ulva* sp.	0,43
Pterocladiella sp.	9	3.78	0.25	Ulvophyceae	0,43
				Sargassum sp.	1,71
CLOROPHYTA	22	9.24	0.37	Rodophyta undentified	2,14
Halimedaceae	1	0.42	0.09	Clorophytas undentified	0,43
Derbesia sp.	1	0.42	0.09	Phaeophytas undentified	
Cladophorales	3	1.26	0.15		
Cladophoraceae	1	0.42	0.09	**WITHOUT PARASITES**	
Chaetomorpha antennina	3	1.26	0.15	**INFECTION**	0,85
(Bory) Kützing				Gelidiaceae	0,43
Chaetomorpha sp.	1	0.42	0.09	*Gelidium* sp.	0,85
Codium sp.	3	1.26	0.15	*G. floridanum*	3,42
Ulvophyceae	1	0.42	0.09	*Hypnea* sp	0,85
Ulvaceae	1	0.42	0.09	*Kappaphycus alvarezii*	0,43
Ulva sp.	26	10.92	0.39	Gracilariaceae	2,99
				Gracilaria sp.	1,71
PHAEOPHYTA	3	1.26	0.15	*Pterocladiella* sp.	0,43
Colpomenia sp.	1	0.42	0.09	Halimedaceae	0,43
Petalonia sp.	1	0.42	0.09	*Derbesia* sp.	1,28
Dictyopteris sp.	1	0.42	0.09	Cladophorales	0,43
Sargassaceae	1	0.42	0.09	Cladophoraceae	0,85
Sargassum sp.	18	7.56	0.34	*Chaetomorpha antennina*	0,43
				Chaetomorpha sp.	0,85
ALGAE (NI) undentified	37	15.55	0.45	*Codium* sp.	0,43
				Ulvaceae	9,83
Plant fragments	1	0.42	0.09	*Ulva* sp.	0,43
				Dictyopteris sp.	0,43
Animals				*Petalonia* sp.	0,43
Cnidaria	1	0.42	0.09	Sargassaceae	7,26
Molluska	3	1.26	0.15	*Sargassum* sp.	4,7
Thecosomata	1	0.42	0.09	Rodophyta undentified	7,26
Crustacea	1	0.42	0.09	Clorophytas undentified	0,85
Amathia sp.	3	1.26	0.15	Phaeophytas undentified	
Shell	3	1.26	0.15		
Fish ni	2	0.84	0.12		

Anthropogenic materials					
Nylon	13	5.46	0.29		
Fishing line	1	0.42	0.09		
Hair	2	0.84	0.12		
Clothing tissue	1	0.42	0.09		
String	2	0.84	0.12		
Cotton thread	3	1.26	0.15		
Synthetic Sponge	2	0.84	0.12		
Plastic	17	7.14	0.33		
Plastic straw	1	0.42	0.09		
Baloon	1	0.42	0.09		
Rubber	1	0.42	0.09		
Rope	1	0.42	0.09		
Fishing hook	2	0.84	0.12		

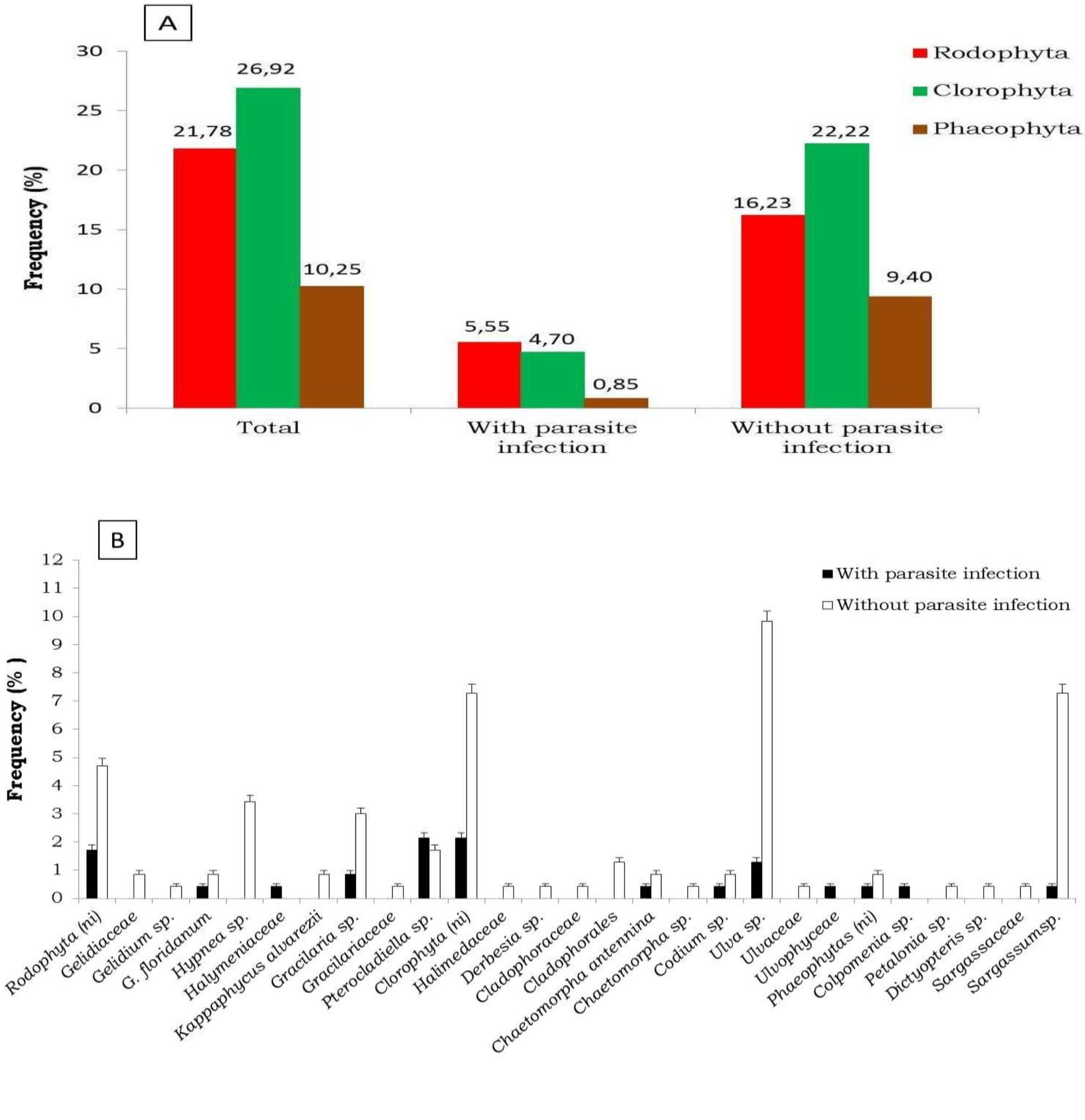

Figure 1: Items analyzed in the digestive tract of the green sea turtle *Chelonia mydas* stranded in Rio de Janeiro state. Graph A shows the frequency (%) of total Rodophyta, Chlorophyta and Phaeophyta on turtles with or without parasites. Graph B shows different algae taxa in the digestive tract.

4. Discussion

Food intake studies are vital to understanding the ecological role of organisms and their trophic interactions [23,24]. Turtles diet composition can be studied by different techniques, including analysis of gut contents from dead turtles and esophageal lavage and fecal examination [25, 26].

In the present study we analyzed a total of 137 stranded green sea turtles, according to the presence of parasites and their digestive tract content. Statistical analysis demonstrated that the main algae group ingested by infected sea turtles were mainly Chlorophyta and Rodophyta. Non infected turtles also ingested these groups of algae additionally to Phaeophyta.

The juvenile green sea turtle in Rio de Janeiro state shore consumed mostly algae and this data is supported by the dietary shift from the pelagic to the inshore stage, reported by Arthur and his colleagues (2008) [27] . Although some invertebrates have been observed in their diet composition, our data suggest that these animals are in the stage of changing their omnivorous feeding habit to a primarily herbivorous consumer. Our data also corroborate Carrión-Cortez and his colleagues (2010) [28] diet report for this same species in Galapagos, as well as by Amorocho & Reina (2007) [29] in Colombia.

The major contribution of Clorophytes in the green sea turtle diet was also reported by Santos and his colleagues (2011) [30] in a degraded habitat, in contrast to other studies around the world, reporting Rodophytes as predominated item [31, 34]. The major consumption of Clorophytes might be related to availability, as reported by Santos and his colleagues (2011) [30]. Degraded habitats, mainly caused by eutrophication, might have a predominance of Clorophytes due to their biological capacity to process nutrients and improve biomass, driving animal consumption. However, our data revealed that infected sea turtles consumed equally Clorophytes and Rodophytes, on the other hand, non-infected animals consumed mostly Clorophytes. Previous studies proposed that animals with parasite infection may adjust their food intake quantity and quality to optimize their foraging. Therefore, they might reduce or improve the amount of food, as well as change the preys to optimize their nutritional deficiency. Although Clorophytes might be the most consumed item in the present study, Rodophytes seemed to be an important item for sea turtles around the world [31, 34], suggesting that they might provide a particularly important nutrient for a healthy individual. Both Clorophytes and Rodophytes have, in general, similar amount of proteins (Clorophytes: 32–352 g-1kg; Rodophytes: 64–376 g-1kg) and polysaccharides (Clorophytes: 150–650 g-1kg; Rodophytes: 360–660 g-1kg), however, Rodophytes have larger concentration of lipids (Clorophytes: 3–28 g-1kg; Rodophytes: 2–129 g-1kg), what could possibly explain, their largest consumption, due to energy requirement of sea turtles with parasitic infection.

Another issue on diet shift could be related to digestion efficiency. Several factors can influence the digestion efficiency of *C. mydas* (eg. competition for resources and temperature), which leads to a change in diet [35, 36*]. In this study we could observe a change in species composition and algal frequency in green turtles with and without parasites. The turfed macroalgal species *Hypnea* sp. and *Gelidium* sp. is frequently reported in the literature as part of the diet of *C. mydas* [33, 37, 38] and the same was observed in our results in non-parasitized green turtles. However, the parasitized green turtles did not consume *Hypnea* sp. and *Gelidium* sp., a pattern opposite as expected. Turf algae were characterized by height-producing organisms dominant in shallow waters and provide high absorption rate of nutrient and minerals (39). Another important change was the reduction in consumption of *Sargassum* sp. in green turtles with parasites, and those not parasitized apparently have a preference for this alga among the Phaeophyta. Moreover, another important component of not parasitized green turtles was the Chlorophyta *Ulva* sp., which was a pattern different from that observed by Holloway-Adkins & Hanisak (2017) [38], who reported a major ingestion of Rodophyta. Turtles with parasites consumed most frequently *Pterocladiella* sp. and *Ulva* sp., both are rich in soluble and insoluble fibers [40], improving digestion efficiency. It should be expected since parasitized animals have an increased demand of nutrients, needing to improve their digestion efficiency.

Rocha and his colleagues (2022) [45] reported that most of the parasite infections caused in the green sea turtle from Rio de Janeiro are gastrointestinal parasites, which could also explain the sudden change in food intake variety. The study of Lockley and his colleagues (2020) in the loggerhead sea turtle reported a slight difference in trophic niche, as we found in our study [22].

Although our results reported a dietary shift in the type of food ingested, our study has some limitations, considering quantitative consumption. We did not quantify the amount of food consumed to compare both groups and suggest food intake reduction, as well as our results did not relate the amount of parasites and the dietary shift. Therefore, although we highlight some important issues, considering qualitative feeding ecology of the green sea turtle in a vulnerable condition of infection, further studies are necessary, highlighting the quantification of each food content consumed and its correlations to infection degree.

Anthropogenic debris such as plastic bags, nylon chord, and tarpaulin fragments has been usually found in several gastrointestinal samples of stranded *C. mydas* [25, 40, 42] . Previous studies have observed plastic materials in the stomachs of 70% examined sea turtles [40, 43]. In the present study, anthropogenic materials consumption was also identified on both infected and non infected *C. mydas*. Despite statistical analysis having demonstrated no significant difference concerning trash ingestion, previous studies have shown that plastic debris may not have any immediate lethal effect on the turtle, but can interfere with the nutritional value of a diet, food digestion and absorption [35]. Beside that, studies have demonstrated that indirect disturbances to the immune system may occur due to chemical contaminants and anthropogenic debris [40, 41]. These results can be mainly observed in green turtle populations adjacent to regions associated with agriculture, industry and urban development. Due to numerous anthropogenic threats and population declines, the green turtle had been listed as globally endangered on the IUCN Red List [44].

5. Conclusion

The present study remarks that parasitic infection seems to provide a dietary shift, reducing the food items diversity and changing algae richness. Although parasites are not correlated specifically to trash ingestion. More studies are necessary to better understand anthropogenic debris and parasites infection effects on food intake of stranded juvenile green turtles *Chelonia mydas*.

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