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Plastic ingestion by sea turtles in Paraíba State, Northeast Brazil

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ABSTRACT. Currently, plastics are recognized as a major pollutant of the marine environment, representing a serious threat to ocean wildlife. Here, we examined the occurrence and effects of plastic ingestion by sea turtles found stranded along the coast of Paraíba State, Brazil from August 2009 to July 2010. Ninety-eight digestive tracts were examined, with plastic found in 20 (20.4%). Sixty five percent (n = 13) of turtles with plastic in the digestive tract were green turtles (*Chelonia mydas*), 25% (n = 5) were hawksbills (*Eretmochelys imbricata*), and 10% (n = 2) were olive ridley (*Lepidochelys olivacea*). More plastic was found in the intestine (85%) than in other parts of the gastrointestinal tract. We observed complete blockage of the gastrointestinal tract due to the presence of plastic in 13 of the 20 turtles that had ingested plastic. No correlation was found between the curved carapace length (CCL) and the number or mass of the plastic ingested items. Significant differences were found between the intake of hard and soft plastic and the ingestion of white/transparent and colored plastic, with soft and white/transparent plastics being more commonly ingested. This study reveals the serious problem of plastic pollution to sea turtles at the area.

KEYWORDS. Marine debris ingestion, gastrointestinal blockage, *Chelonia mydas*, *Eretmochelys imbricata*, *Lepidochelys olivacea.*

RESUMO. Ingestão de plástico por tartarugas marinhas no estado da Paraíba, Nordeste do Brasil. Atualmente, os plásticos são reconhecidos como um dos principais poluentes do ambiente marinho, representando uma séria ameaça para a vida marinha. Neste trabalho, nós examinamos a ocorrência e os efeitos da ingestão de plástico por tartarugas marinhas encontradas encalhadas ao longo da costa do estado da Paraíba, Brasil, de agosto de 2009 a julho de 2010. Noventa e oito tratos gastrointestinais foram examinados e plásticos foram encontrados em 20 (20,4%). Sessenta e cinco por cento (n = 13) das tartarugas com plástico no trato gastrointestinal eram da espécie verde (*Chelonia mydas*), 25% (n = 5) eram da espécie pente (*Eretmochelys imbricata*) e 10% (n = 2) eram da espécie oliva (*Lepidochelys olivacea*). Foi encontrado mais plástico no intestino (85%) do que em outras partes do trato gastrointestinal. Observou-se o completo bloqueio do trato gastrointestinal, devido à presença de plástico, em 13 das 20 tartarugas que ingeriram plástico. Não foi encontrada correlação entre o comprimento curvilíneo de carapaça (CCC) e o número ou massa dos itens plásticos ingeridos. Diferenças significativas foram encontradas entre a ingestão de plástico rígido e flexível e entre a ingestão de plástico branco/transparente e colorido, com os flexíveis e brancos/transparentes sendo ingeridos com mais frequência. Este estudo revelou o grave problema da poluição por resíduos plásticos para as tartarugas marinhas nesta área.

PALAVRAS-CHAVE. Ingestão de lixo marinho, bloqueio gastrointestinal *Chelonia mydas*, *Eretmochelys imbricata*, *Lepidochelys olivacea*.

Sea turtles face a number of anthropogenic threats associated with marine pollution including trash, oil spills and the bioaccumulation of chemicals (Hutchinson & Simmonds, 1992). Plastics are currently recognized as one of the most important pollutants in marine and coastal environments, and are reported in many studies as the main type of anthropogenic debris found in these habitats (Ivar do Sul & Costa, 2007; Sheavly & Register, 2007; Ryan *et al.*, 2009). Estimates reveal that at least 5.25 trillions of plastic particles are currently floating in the sea, totaling 268,940 tons (Eriksen *et al*., 2014). Once in the environment, plastics can impact wildlife in a number of ways, including entanglement and ingestion (Tourinho *et al*., 2010). Plastic ingestion by seabirds, turtles, marine mammals, fishes, and invertebrates has been widely reported over the last decades (Laist, 1997; Stamper *et al*., 2006; Graham & Thompson, 2009; Schuyler *et al*., 2012). Sea turtles are prone to this ingestion, which may occur when plastic items are mistaken for natural food such as jellyfish, or when items are accidentally ingested with food (Laist, 1987; Schuyler *et al*., 2014).

The physical and chemical effects of plastic ingestion on sea turtles are widely recognized (McCauley & Bjorndal, 1999; Bugoni *et al*., 2001; Lazar & Gračan, 2011). When ingestion levels are low, effects are generally sublethal, but can ultimately increase the probability of death (Hutchinson & Simmonds, 1992). For example, nutritional dilution can occur when non-nutritious items occupy the food space in the gastrointestinal tract, affecting the nutritional gain and consequently growth and reproduction rates (McCauley & Bjorndal, 1999). Related sublethal effects also include damage to the gastrointestinal tract such as necrosis and ulceration (Bjorndal, 1997), and loss of buoyancy control due to the increased time food remains in intestinal tract compartments, accumulating gas in the intestine (George, 1997). Lethal effects occur when residues directly obstruct the digestive tract, blocking the passage of food (Bjorndal *et al*., 1994; Bugoni *et al*., 2001; Tourinho *et al*., 2010).

Northeastern Brazil is recognized as an important feeding and nesting area of at least four sea turtle species: hawksbill (*Eretmochelys imbricata* Linnaeus, 1766), loggerhead (*Caretta caretta* Linnaeus, 1758), olive ridley (*Lepidochelys olivacea* Eschscholtz, 1829), and green turtles (*Chelonia mydas* Linnaeus, 1758; Marcovaldi & Marcovaldi, 1999; Silva *et al*., 2007; Peres *et al*., 2011). Along the coast of Paraíba State, green turtles commonly use the reefs close to the shore as feeding grounds (Mascarenhas *et al.*, 2005), and hawksbills use the beaches for nesting (Mascarenhas *et al.*, 2003). Moreover, loggerhead, green, hawksbill and olive ridley turtle strandings have been recorded (Mascarenhas *et al.*, 2005; Mascarenhas & Iverson, 2008).

In Brazil, the few studies that report plastic ingestion by sea turtles were conducted in the southern portion of the country (e.g., Bugoni *et al.*, 2001; Tourinho *et al.*, 2010). In Paraíba State, there is a single published record of plastic ingestion by one green and one olive ridley turtle (Mascarenhas *et al.*, 2004). Nevertheless, many unpublished records from the local project "Tartarugas Urbanas" indicate a possible increase of plastic ingestion by sea turtles that use waters adjacent to urbanized regions of the Paraíba coast. Given the low number of studies on how plastic ingestion affects sea turtles in northeastern Brazil and the importance of Paraíba state as a nesting and feeding ground, this study aims to analyze the effects of plastic ingestion on sea turtles along the coast of this state, registering the occurrence and possible lethal effects of this ingestion and providing valuable information for sea turtle conservation.

MATERIALS AND METHODS

This study was conducted from August 2009 to July 2010 on the coast of Paraíba State, northeastern Brazil, along 15 km of urban beaches in the municipalities of João Pessoa (7°08'S and 34°48'W) and Cabedelo (7°01'S and 34°49'W). We performed daily stranding surveys between Bessa beach (7°05'S and 34°49'W) and Ponta de Campina beach (7°01'S and 34°49'W, Fig. 1). For the remaining areas (Cabo Branco, Tambaú and Manaíra beaches, Fig. 1), stranding observations were communicated to us via a telephone line, "SOS Tartarugas". After communication by phone, we went to the stranding location to collect and record stranding data.

For each turtle stranded (dead or alive) we identified species and measured curved carapace length (CCL). Species were identified based on morphological characteristics according to international standards described in Pritchard & Mortimer (1999). We obtained CCL to an accuracy of 0.1 cm using a flexible measuring tape. Individuals were classified as juveniles or adults based on CCL measurements, with animals equal to or larger than the minimum CCL of nesting females on nearby beaches considered adults (see Grossman *et al.*, 2007; Silva *et al.*, 2007; Santos *et al.*, 2010 for reference values). Live individuals were transported for rehabilitation under the care of the Tartarugas Urbanas project.

Carcasses that were not in advanced stages of decomposition were necropsied to sample the gastrointestinal tract. Gastrointestinal tracts were removed from the esophagus to the final portion of the intestine (Wyneken, 2001) and each segment was analyzed separately (esophagus, stomach and intestine). Gastrointestinal contents were manually extracted using tweezers and washed in tap water using sieves. When

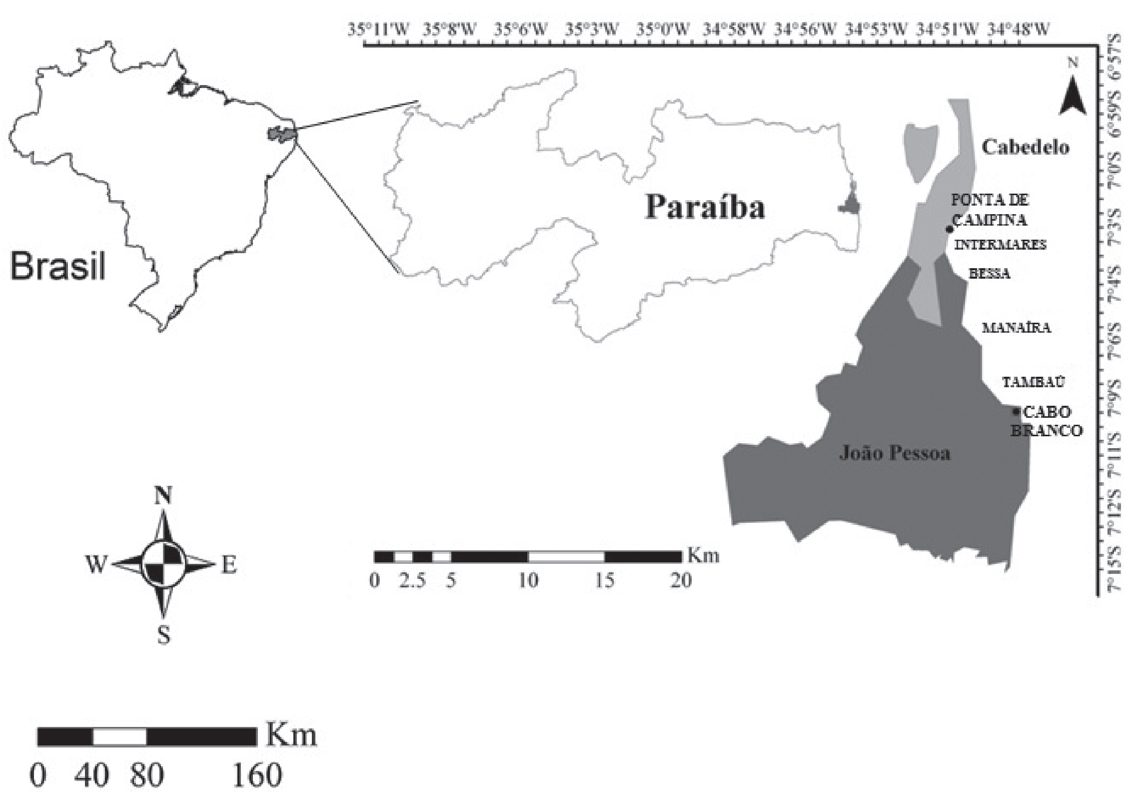

Fig. 1. Study area and monitored beaches in Cabedelo and João Pessoa Municipalities, Paraíba State, Brazil.

present, plastics were separated from organic items, dried, measured, weighed, and classified according to their structure (soft or hard plastic) and color (colored or white/transparent). Individuals that died during rehabilitation underwent the necropsy procedure described above.

The representativeness of ingested plastic types was recorded as frequency of occurrence (FO%), as follows: FO% = Number of animals that consumed the plastic type/Total number of animals with plastic in their gastrointestinal tract * 100. The data used in statistical analysis that did not show normal distribution according to a D'Agostino–Pearson's test were normalized using a Neperian log (Ayres *et al.*, 2007). Pearson's correlations (Ayres *et al.*, 2007) were carried out between CCL and the amount (in numbers of pieces and total mass) of ingested plastic items. We performed a *t*-test for independent samples (Ayres *et al.*, 2007) to compare the composition of plastic items (type and color) in the gastrointestinal tract. For all statistical analysis, results were considered significant if $P < 0.05$ (Zar, 1999).

RESULTS

During the study period, 124 sea turtle strandings were recorded at the study area: 106 Green Turtles (85.4%), 15 Hawksbill (12.1%), two Olive Ridley (1.6%) and one Loggerhead (0.9%). Fifteen turtles (12.1%) were stranded alive, but died during the rehabilitation period due to various complications, including plastic ingestion. We collected 98 gastrointestinal tracts based on decomposition of carcasses, being 84 Green Turtles, 12 Hawksbills and two Olive Ridley. Plastic residues were found in 13 Green Turtles (15.5% - CCL range 29.1 – 85.6 cm, mean = 44.15 cm, SD ± 15.5 cm), five Hawksbills (41.7% - CCL range 29.6 – 89.3 cm, mean = 44.68 cm, SD ± 25.09 cm) and two Olive Ridley (100% - CCL range 60 – 63.3 cm, mean = 61.65 cm, SD ± 2.33 cm). Only one turtle (hawksbill, CCL = 89.3 cm) was classified as an adult. Among the 20 individuals with plastic in their gastrointestinal tract, 13 (65% - nine green and four hawksbill turtles) had their tract blocked by plastic, which resulted in death. Among these 13 individuals, 10 were initially found alive but were debilitated and emaciated, indicating that they had not been feeding normally prior to stranding. Twelve individuals (60%) had plastic only in the intestine, three (15%) only in the stomach, and five (25%) in both the stomach and intestine. We did not find plastic fragments in the esophagus of any turtle.

A total of 361 anthropogenic plastic items were ingested by all individuals, ranging from one up to 87 items per turtle (mean = 18.1, SD ± 20.4 items, Tab. 1). The total mass of plastic in the gastrointestinal tracts among all turtles was 114.9 g, ranging from 0.01 g to 63.5 g/individual (mean = 5.7 g, SD ± 14.1 g/individual; Tab. 1). Regarding the 13 turtles with blocked gastrointestinal tracts, the number and mass of plastic ranged from seven to 87 items per turtle and 0.1 g to 63.5 g/individual. We did not find a significant correlation between CCL and the number of ingested plastic items ($R = -0.15$, $P = 0.5$, n = 20), or between CCL and the mass of ingested plastic per turtle ($R = 0.0182$, $P = 0.9$, n = 20). Most ingested items were soft plastics (310 items, 85.9%; Tab. 1), with an average of 15.5 (± 19) items per turtle. Hard plastics amounted to 51 items (14.1%; Tab. 1), with an average of 2.5 (± 4.4) items per turtle. We found significant difference between the number of soft and hard plastic ingested ($t = 4.6$, $P = 0.0001$; soft plastics FO% = 95%, hard plastics FO% = 50%). There was also a significant difference between the number of white/transparent and colored plastics ingested ($t = -2.9$; $P = 0.005$). White/transparent plastics were more common, accounting for 258 items ($\bar{x} = 12.9 \pm 16$ items

Tab. I. Raw data on plastics collected in the gastrointestinal tract of sea turtles in Cabedelo and João Pessoa Municipalities, Paraíba State, Brazil.

Species	CCL	Items	Mass (g)	Soft plastic	Hard plastic	White/transparent plastic	Colored plastic	Color of plastic				
								Black	Blue	Green	Pink	Yellow
CM	29.1	26	4.65	25	1	24	2	1	0	0	1	0
CM	29.9	10	1.23	8	2	8	2	2	0	0	0	0
CM	33.7	14	1.39	11	3	10	4	2	0	0	1	1
CM	35.2	7	0.57	7	0	5	2	1	1	0	0	0
CM	36	8	0.16	8	0	8	0	0	0	0	0	0
CM	37	1	0.01	1	0	0	1	0	1	0	0	0
CM	39.1	5	0.34	5	0	5	0	0	0	0	0	0
CM	41.3	15	0.33	15	0	15	0	0	0	0	0	0
CM	43.6	8	0.11	8	0	5	3	0	2	1	0	0
CM	47.5	2	0.11	2	0	2	0	0	0	0	0	0
CM	55.4	17	6.03	13	4	11	6	4	1	1	0	0
CM	60.5	1	0.33	1	0	1	0	0	0	0	0	0
CM	85.6	87	63.53	84	3	73	14	10	2	2	0	0
EI	30.9	40	9.96	30	10	20	20	13	2	5	0	0
EI	31	35	1.9	32	3	8	27	1	0	26	0	0
EI	35	35	9.22	31	4	22	13	4	8	1	0	0
EI	37.2	31	12.74	13	18	23	8	3	0	3	2	0
EI	89.3	12	0.37	12	0	12	0	0	0	0	0	0
LO	60	4	0.13	4	0	4	0	0	0	0	0	0
LO	63.3	3	1.81	0	3	2	1	0	0	1	0	0

per turtle; FO% = 95%; Tab. 1). Colored plastics (black, blue, green, red and yellow) accounted for 103 items ($\overline{x}$ = 5.1 ± 7.6 per turtle; FO% = 65%; Tab. 1).

DISCUSSION

All sea turtles species are prone to the ingestion of plastic, which may occur accidentally, when these residues are confused with their natural foods such as jellyfish, or when they are ingested with food (Mrosovsky *et al*., 2009; Schuyler *et al*., 2014). In previous studies, Green Turtles were the main species ingesting plastic (Bugoni *et al*., 2001; Tourinho *et al*., 2010; Guebert-Bartholo *et al*., 2011), but in this study, proportionally, the plastic ingestion incidence was higher in Hawksbills turtles. . Probably, the predominant number of Green Turtles in the present study was due to the fact this species use the coral reefs of the Paraíba coast as a feeding ground (Mascarenhas *et al*., 2005), favoring their stranding in the study area. Green turtles may be especially prone to plastic ingestion, since this type of debris is commonly found adhered to their main food resource, algae (Reis *et al*., 2010), but Schuyler *et al*., (2012) not found significant difference in the plastic ingestion between Green and Hawksbill species. Both species, exhibit similar feeding behavior, with smaller turtles feeding pelagically, and larger turtles shifting to benthic feeding (Bjorndal, 1997). We did not find a correlation between CCL and the number or mass of ingested plastic items, which is consistent with other studies (Bugoni *et al*., 2001; Tourinho *et al*., 2010; Lazar & Gračan, 2011). Although some studies have suggested that juveniles are more prone to plastic ingestion (Balazs, 1985; Bjorndal, 1997; Schuyler *et al*., 2012); however, we can not presume the same, since in this study only one adult animal was observed.

Our study showed a lower plastic ingestion rate for Green Turtles when compared to previous works (Bugoni *et al*., 2001; Tourinho *et al*., 2010; Guebert-Bartholo *et al*., 2011; see Tab. 2). Perhaps this lower ingestion rate observed for green turtles is related to a lower availability of plastic in the feeding grounds of these populations. Nonetheless, our most important finding in terms of conservation involves the lethal effects of plastic ingestion observed in stranded sea turtles. Previous studies have reported a low occurrence of sea turtle deaths related to plastic ingestion (Plotkin *et al*., 1993; Mrosovsky *et al*., 2009; Guebert-Bartholo *et al*., 2011), with some authors assuming that death caused by plastic blockage of the intestine is only occasional (Tomás *et al*., 2002; Mrosovsky *et al*., 2009). Here we report a relatively large number of sea turtles deaths caused by plastic ingestion (Tab. 2), and higher amounts and mass of plastic items ingested by individual turtles than those mentioned in other works (Bugoni *et al*., 2001; Lazar & Gračan, 2011). However, the plastic mass found in turtles with blocked gastrointestinal tracts was smaller (Bjorndal *et al*., 1994; Bugoni *et al*., 2001; Lazar & Gračan, 2011). Bjorndal *et al*. (1994) reports that turtles can die with just a small amount of plastic in their gastrointestinal tract, which in their study ranged from 2.2 to 6.5 g).

In the present study we examined the entire gastrointestinal tracts, and found that plastics were most common in the intestines of turtles. Most works reporting plastic ingestion have been associated with dietary studies, frequently using only the contents of the esophagus and stomach that likely underestimates plastic ingestion. Other studies have also indicated that the intestines hold a larger amount of plastic than the esophagus and stomach (Bjorndal *et al*., 1994; Tomás *et al*., 2002). We suggest that future studies evaluate the entire gastrointestinal tract of turtles, so we can get more reliable estimates.

White/transparent plastic items were ingested significantly more frequently than colored plastic items. Previous studies also reported a higher ingestion of white/transparent plastic (Bugoni *et al*., 2001; Lazar & Gračan, 2011; Schuyler *et al*., 2014). Carr (1987) and Gramentz (1988) attribute the higher frequency of white/transparent plastic ingestion to the fact that turtles

Tab. II. Occurrence of plastic ingestion by sea turtles and lethal cases related with this ingestion based on literature data and present study [CM, *Chelonia mydas*; CC, *Caretta caretta*; DC, *Dermochelys coriacea* (Vandelli, 1761); EI, *Eretmochelys imbricata*; LK, *Lepidochelys kempii*; LO, *Lepidochelys olivacea*].

Study area	Occurrence of ingestion by species *n* (%)	Total occurrence of ingestion *n* (%)	Lethal cases by species	Total of lethal cases	Reference
Northwestern Gulf of Mexico	CC = - (51.2%)	(51.2%)	CC = 3	3	Plotkin *et al*.,1993
Adriatic Sea	CC = 19 (35.2%)	19 (35.2%)	CC = 1	1	Lazar & Gračan, 2011
Western Mediterranean	CC = 43 (79.6%)	43 (79.6%)	0	0	Tomás *et al*., 2002
Southern Brazil	CM = - (69.7%)	(69.7%)	CM = 3	3	Guebert-Bartholo *et al*., 2011
Southern Brazil	CM = 23 (60.5%)	23 (60.5%)	CM = 4	4	Bugoni *et al*., 2001
Florida Coast	CM = 24 (56%) CC = 1 (100%) LK = 0	25 (49%)	-	2	Bjorndal *et al*., 1994
Southern Brazil	CM = 34 (100%)	34 (100%)	CM = 3	3	Tourinho *et al*., 2010
Multiple areas	DC = 138 (33.8%)	138 (33.8%)	DC = 12	12	Mrosovsky *et al*., 2009
Paraíba Coast	CM = 13 (15.5%) EI = 5 (41.7%) LO = 2 (100%)	20 (20.4%)	CM = 9 EI = 4	13	This study

mistake this color of plastic with jellyfish, which is a common item in the diet of some sea turtle species. Green and loggerhead turtles maintained in captive conditions will ingest plastics that are either colored (blue, yellow, pink) or white/transparent, with the former ingested less frequently (Lutz, 1990). Schuyler *et al*., 2014 suggested that sea turtles consume less blue plastics because they can be less visible in the open water background where they forage. Soft plastic was the most common kind of plastic found in our study, corroborating the results of previous studies (Tourinho *et al*., 2010; Lazar & Gračan, 2011; Schuyler *et al*., 2014). The main hypothesis supported is that the turtles select debris similar to your food type, such as jellyfish, but the plastic availability in the feeding substrate of these populations should also be considered. However, the availability of type and color of plastic in the coastal area of Paraíba is still unknown, and it is therefore not possible to evaluate if white and soft plastics were selected in greater proportion than their availability in the environment. However, specific studies in these areas are needed in order to test the hypothesis. Our results reveal for the first time the serious threat to sea turtles in Northeastern Brazil. We observed that sea turtles at the Paraíba coast ingest plastic in large amounts, resulting in high mortality level. These data indicate that coastal habitats used by sea turtles in this region are contaminated with plastic, and that the consequences of plastic ingestion may be severe. Effective measures to minimize plastic pollution are needed to contribute towards the conservation of sea turtles and others species. More studies are required to determine whether the high percentage of deaths we found to be associated with the ingestion of plastic is just an isolated case, or if this is a consistent and perhaps increasing problem in northeast Brazil. Additional studies are also needed to determine the sublethal effects of plastic ingestion, such as the absorption of toxins through the intestine and its consequences, as well as specific studies quantifying the amount of plastic in this environment.

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