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Ingestion of Marine Debris by Juvenile Sea Turtles in Coastal Florida Habitats

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Digestive tracts from 51 sea turtle carcasses that washed ashore on the east and west coasts of Florida were examined for the presence of anthropogenic debris. Debris was found in 24 of 43 green turtles (*Chelonia mydas*), 0 of 7 Kemp's ridleys (*Lepidochelys kempi*), and 1 of 1 loggerhead (*Caretta caretta*). Ingested debris included plastic, monofilament line, fish hooks, rubber, aluminium foil, and tar. For green turtles, ingestion of debris was not significantly affected by location of stranding, season, or body size. Debris ingestion was significantly affected by sex of the turtle. Frequency of occurrence of debris was significantly higher in females, but differences in the mass or volume of ingested debris were not significantly different between the sexes. Although frequency of occurrence of debris was high in green turtles (56%), the mass and volume of the debris were small—mean 0.52% of wet mass of gut contents and mean 0.72% of the volume of gut contents, respectively. However, small quantities of debris can kill sea turtles; the death of at least two turtles in this study resulted from debris ingestion. The debris in the two turtles represented 4.6% and 5.8% of wet mass and 3.2% and 9.8% of volume of the gut contents, respectively. In both turtles, the debris represented inflated percentages because the turtles had not been feeding normally prior to death because the debris affected gut function. Sublethal effects of debris ingestion (e.g. absorption of toxins) has an unknown—but potentially great—negative effect on the demography of sea turtles.

Although there had been scattered reports of ingestion of marine debris by sea turtles, it was not until Balazs (1985) compiled a thorough summary of reports, both published and unpublished, that ingestion of debris was recognized as a serious threat to sea turtle populations throughout the world. Carr (1987) then focused attention on the consequences of concentration of debris in driftlines inhabited by pelagic sea turtles. Balazs (1985) and Carr (1987) stressed the need to quantify the ingestion of debris by sea turtles and to estimate the mortality resulting from debris ingestion. The importance of these studies was reinforced by the report of the Sea Turtle Conservation Committee of the US National Academy of Sciences (Magnuson *et al.*, 1990). The Committee concluded that, although the negative impact of marine pollution on sea turtle demography may be very significant, the mortality resulting from marine pollution was one of the most difficult to estimate of all human-induced sources of mortality.

As Laist (1987) has discussed, it is difficult to estimate the mortality resulting from ingestion of debris in marine organisms. However, strandings of sea turtle carcasses on coastlines around the world offer an opportunity to assess debris ingestion in relatively large samples of turtles. We examined the digestive tracts from 51 sea turtle carcasses that stranded in Florida for the presence of debris.

Methods

A network of volunteers, organized by the Florida Department of Natural Resources, monitors stranding events of sea turtles throughout Florida. Beginning in 1988, we requested that dead sea turtles with carapace lengths of less than 40 cm be frozen and shipped to us at the University of Florida. We collected only small turtles because of our interest in early life stages and the difficulties of transporting and storing large specimens. Some turtles larger than 40 cm were received and were included in the study.

Date and location of stranding and cause of death, if known, was obtained from the volunteers. Straight carapace length was measured from nuchal notch to posterior notch. Sex was determined by visual inspection of the gonads. The mouth of each turtle was opened and inspected for debris, and the digestive tract was removed from the body cavity. The contents of each section (esophagus, stomach, small intestine and large intestine) were weighed (wet mass) to ± 0.1 g and the volume was recorded to ± 0.1 ml. The contents of each section were then thoroughly examined for anthropogenic debris. The location within the gut was recorded for any debris that was found, the debris was weighed, and its volume recorded.

Ingestion of debris was quantified in three ways: *1.* As the number of turtles in which debris was found, or frequency of occurrence; *2.* As percent of wet mass of gut contents of each animal; and *3.* As percent of volume of gut contents of each turtle. Because of the

small numbers of Kemp's ridleys and loggerheads, only data for green turtles were analysed for effects of stranding location, season, size, and gender on debris ingestion. Percentages were arcsine-transformed for statistical analyses (Ryan *et al.*, 1985; Zar, 1984). Alpha was 0.05.

Results and Discussion

Turtles received

Fifty-one sea turtles with digestive tracts sufficiently intact to allow examination were received after they washed up dead on Florida beaches. A few of the turtles that we examined had been in poor condition before death, and therefore probably had not been feeding normally, as indicated by their empty, or nearly empty, digestive tracts. However, most of the carcasses represented healthy turtles that had been killed by collisions with boats or by incidental capture in fisheries. Thus, the carcasses that strand in Florida, as well as in many other parts of the world, offer the opportunity to study the feeding habits of healthy, actively foraging turtles.

The sample included 43 green turtles (*Chelonia mydas*), 7 Kemp's ridleys (*Lepidochelys kempi*), and 1 loggerhead (*Caretta caretta*). For the green turtles, 18 were females, 19 were males, and the sex of six could not be determined due to deterioration of the gonads. Carapace length of green turtles varied from 20.6 to 42.7 cm. There was no significant difference in carapace lengths between males and females (t-test, $n=37$, $P=0.69$). Six of the green turtles stranded on the west coast of Florida between St. Petersburg Beach, Pinellas County, and North Bay, Panama City, Bay County. On the east coast, 37 green turtle carcasses were collected between Miami Beach, Dade County, and Little Talbot Island, Duval County, with the majority from Martin, St. Lucie and Indian River counties.

The ridleys were five females and two males. Carapace length varied from 28.6 to 66.2 cm. All of the ridleys stranded on the west coast between Panacea, Wakulla County, and Fort Walton Beach, Okaloosa County. The loggerhead was a female with a carapace length of 52.0 cm, which stranded on the east coast at Crescent Beach, St Johns County. The loggerhead is the most common species in Florida waters, and carcasses of loggerheads frequently strand on Florida beaches. We only received one loggerhead carcass because we had requested carcasses of turtles with less than 40 cm carapace length. Few loggerheads between 4.5 cm (the size of hatchlings) and 40 cm inhabit Florida waters.

Incidence of marine debris ingestion

Of the 43 green turtles, 24 (56%) had ingested marine debris (Table 1). Although cause of death could not be determined in all cases, it was clear that the death of two green turtles had resulted from ingestion of marine debris. Both turtles were emaciated, the gut tissue around the debris was necrotic, and digesta could not pass through the digestive tract.

Debris was located in the mouth of two turtles, in the esophagus of four turtles, in the stomach of two turtles, in the small intestines of five turtles, and in the large intestines of 17 turtles. Five green turtles had debris in more than one segment of the digestive tract. The distribution of debris in the gut indicates that if only esophagus and stomach samples are examined—as is often done in analysis of feeding habits—the incidence of debris ingestion would be underestimated. In our study, frequency of debris ingestion would have been reduced from 24 of 43 (56%) to 6 of 43 (14%) if only the esophagus and stomach had been examined.

In the 24 green turtles that had ingested debris, the mean mass of debris was 0.52% of the wet mass of the gut contents. The mean volume of debris was 0.72% of the gut contents (Table 1).

None of the seven Kemp's ridleys had ingested debris. In New York Bight, Sadove & Morreale (1990) found that the 44 Kemp's ridleys in their study had not consumed debris, although percent frequency of debris ingestion ranged from 9 to 30% in the other sea turtle species present (loggerheads, green turtles, and leatherbacks, *Dermochelys coriaceae*). It may be that Kemp's ridleys, because they chase and consume more active prey than either the herbivorous green turtle or the loggerhead (Mortimer, 1982), are less likely to ingest debris. However, 29 of 101 Kemp's ridleys (29%) that stranded on the Texas coast had ingested debris (Shaver, 1991).

The loggerhead had ingested pieces of plastic, which were in its esophagus and large intestine. The plastic

TABLE 1

Debris ingestion in three species of sea turtles in Florida. N is number of turtles examined, frequency is frequency of ingestion of marine debris (%), mass and volume are the amount of debris in turtles that ingested debris, expressed as percent of gut content wet mass and volume, respectively.

	Frequency		Mass (%)			Volume (%)		
	N	%	N	Mean (SD)	Range	N	Mean (SD)	Range
C. mydas	43	56	24	0.52 (1.48)	0.002–5.9	24	0.72 (2.11)	0.001–9.9
Male	19	42	8	1.34 (2.42)	0.002–5.9	8	1.65 (3.53)	0.001–9.9
Female	18	83	15	0.12 (0.28)	0.002–1.1	15	0.27 (0.59)	0.002–2.0
L. kempi	7	0	0	–	–	0	–	–
C. caretta	1	100	1	0.6 (–)	–	1	1.0 (–)	–

represented 0.6% of wet mass of gut contents and 1.0% of volume of gut contents.

Types of debris ingested

The frequencies of occurrence of types of debris in the 24 green turtles that had ingested debris were: 17 (71%) had ingested plastic, 9 (38%) had ingested monofilament fishing line, 1 (4%) had ingested fish hooks, 1 (4%) had ingested a piece of purple rubber, 1 (4%) had ingested aluminium foil, and 1 (4%) had ingested tar. Six of the 24 turtles (25%) had ingested more than one type of debris. The turtle with fish hooks had two fish hooks attached to monofilament line in its digestive tract.

The types and relative frequencies of debris found in our study are similar to those reported by others. Plastic is usually the most commonly ingested type of debris. (Balazs, 1985; Plotkin & Amos, 1990; Sadove & Morreale, 1990; Shaver, 1991). One difference is that tar, which was the second most common type of debris ingested by sea turtles in the summary by Balazs (1985) and the type of debris most commonly ingested by loggerheads in the Mediterranean (Gramentz, 1988), was only found in the digestive tract of one green turtle in Florida.

Ingestion of monofilament fishing line is a serious threat to sea turtles. The two turtles in this study that had died as a result of debris ingestion had both ingested monofilament line and exemplified two ways in which monofilament line can stop normal gut function. First, the line causes death when, as a tangled ball, it becomes lodged in the gut, often at valves leading from one gut segment to another, and obstructs flow of digesta. One turtle died when a ball of monofilament line blocked the junction between the small and large intestines. Second, monofilament line can also stop normal gut function and result in death when a strand that extends along a portion of the gut becomes lodged at the anterior end. Normal peristalsis of the gut and movements of the digesta will sometimes result in the gut becoming gathered along the length of the line. This is particularly common when the monofilament line has a fish hook on one end that becomes embedded in the flesh of the digestive tract. The second green turtle that died as a result of debris had a fish hook embedded in its intestine with a 34 cm length of monofilament line attached to it. Prior to death, the intestinal tract had gathered along the monofilament line, so that digesta could not pass through the tract. During the necropsy, the length of the small and large intestines was measured as 107 cm before the line was removed. After the line was removed and the gathers were released, the intestines measured 182 cm.

Significance of debris ingestion

Frequency of occurrence is commonly used in studies of gut contents. However, when data on frequency of occurrence are not coupled with a quantification of the amount present (either mass or volume), the results can be misleading. A food item with high frequency of occurrence may actually make a limited contribution to the diet because it is always present in very small amounts.

Studies of debris ingestion by sea turtles often report high frequencies of occurrence. In our study, 24 of 43 green turtles (56%) had ingested debris. Other studies that report high incidence of debris ingestion include: 9 of 39 green turtles (23%, Hays Brown & Brown, 1982); 19 of 32 sea turtles (59%, Duronslet *et al.*, 1991); 10 of 33 leatherbacks (30%, Sadove & Morreale, 1990); 29 of 101 Kemp's ridleys (29%, Shaver, 1991); and 42 of 82 loggerheads (51%, Plotkin *et al.*, 1993).

However, in those studies that also quantified amount of debris, the quantities appear to be small. In those turtles that had ingested debris in our study, debris averaged 0.52% of wet mass of gut contents with a range from 0.002 to 5.9%, and averaged 0.72% of volume of gut contents with a range from 0.001 to 9.9%. Debris averaged 0.08% of dry mass of gut contents in 101 Kemp's ridleys (Shaver, 1991) and 0.4% dry mass of gut contents in 82 loggerheads (Plotkin *et al.*, 1993).

It is important to put these apparently small percentages in perspective. In our study, ingestion of debris was clearly responsible for the death of at least two turtles, by obstructing the gut. In one turtle the debris represented 4.6% of wet mass and 3.2% of volume; in the second turtle the debris represented 5.8% and 9.8%, respectively. In both of these cases the turtles had not been feeding normally prior to death because the debris affected gut function, so the debris represented inflated percentages. In absolute mass and volume, the debris in the two turtles were 2.2 and 6.5 g and 3.0 and 4.5 ml, respectively. These values fall within the ranges of absolute mass (0.01 to 7.0 g) and absolute volume (0.01 to 5.0 ml) of debris found in the other 22 turtles in which the debris appeared to be passing harmlessly through the gut. Two conclusions can be drawn from these values. First, small amounts of debris can kill a sea turtle, and, second, the predictability of such mortality may well be low. A given piece of debris could pass through the gut of a turtle many times without becoming lodged in the gut, but during one transit, the debris could become oriented in such a way as to block the gut and result in the death of the animal.

Small amounts of debris also could have significant effects on the demography of sea turtles through the absorption of toxins. Lutz (1990) demonstrated that small pieces of latex and plastic sheeting can be retained in the digestive tract of normally feeding sea turtles for up to 4 months, and the latex appeared to have deteriorated during that time. Hutchinson & Simmonds (1992) discuss the potential problems of absorption of plasticizers in sea turtles and present examples from other marine organisms.

Biotic and abiotic factors affecting debris ingestion

The ingestion of debris by green turtles that stranded on the west coast of Florida was compared with that of green turtles on the east coast. The difference in the frequency of occurrence of debris was not significant, although it approached significance (Fisher's exact test,

df = 1, P = 0.051). One of six (17%) of west coast green turtles had ingested debris compared with 23 of 37 (62%) of east coast green turtles. The percent mass (0.01%) and percent volume (0.01%) of the debris ingested by the west coast turtle fell within the range of percentages for the east coast turtles.

Ingestion of debris by green turtles that stranded in cool months (October through March) was compared with that of green turtles that stranded in warm months (April through September) to test for seasonal effect. Of 19 turtles that stranded in cool months, 10 (53%) had ingested debris; 11 of 20 turtles (55%) had ingested debris in warm months. There was no significant difference between seasons (Chi-square = 0.02, df = 1, P > 0.75). For those green turtles that had ingested debris, there was also no significant seasonal effect on the amount of debris ingested, expressed either as percent of mass of gut contents (t-test, n = 21, P = 0.72) or as percent of volume (t-test, n = 21, P = 0.48).

To test for effect of body size, green turtles were divided into two size classes: < 30 cm carapace length and > 30 cm carapace length. This division was intended to separate those green turtles that had just left the pelagic habitat and settled into benthic foraging habitats (20–30 cm carapace length; Bjorndal & Bolten, 1988) from those turtles that had inhabited benthic foraging grounds for a longer period of time (> 30 cm carapace length). The hypothesis was that smaller turtles, being less familiar with available foods in benthic habitats, would be more likely to ingest marine debris as they sampled potential food items. However, there was no significant difference in the ingestion of marine debris between the two size classes. Frequency of occurrence of debris in small turtles (15 of 24 or 63%) was not different from that in larger turtles (9 of 19 or 47%) (Chi-square = 0.985, df = 1, P > 0.25). For those turtles that had ingested debris, there was no difference between the two size classes in the percent wet mass of debris (t-test, n = 24, P = 0.13) or the percent volume of debris (t-test, n = 24, P = 0.13).

Balazs (1985) found that immature sea turtles tended to have higher frequencies of debris ingestion than did mature turtles. Plotkin & Amos (1990) reported a trend for frequency of occurrence of ingestion of debris to decrease with increasing body size in sea turtles in the Gulf of Mexico.

The sex of the green turtles had a significant effect on the frequency of occurrence of marine debris ingestion (Chi-square = 6.68, df = 1, P < 0.01). Eight of 19 male green turtles (42%) had ingested debris, whereas 15 of 18 female green turtles (83%) had debris in their digestive tracts (Table 1). The significance of this difference was maintained if only east coast green turtles were compared (Chi-square = 5.236, df = 1, P < 0.05). Eight of 16 east coast males (50%) had ingested debris, whereas 14 of 16 east coast females (88%) had ingested debris. The only west coast turtle to ingest debris was a female.

The difference between sexes did not extend to quantity of debris ingested. For those green turtles that had ingested debris, there was no significant difference between males and females for the percent mass of debris (t-test, n = 23, P = 0.20) or for percent volume of debris (t-test, n = 23, P = 0.31).

The difference in the frequency of debris ingestion between sexes of immature turtles was not expected and may be a result of the sample sizes. We do not know of any study in which a comparison of frequency of debris ingestion between sexes has been made. Whether this difference is biologically significant will only be known after further study.

Conclusion

It has been established that sea turtles ingest marine debris at high frequencies, but often in small quantities. What remains to be elucidated is the quantitative effects of debris ingestion on mortality of sea turtles. We should not dismiss the ingestion of small amounts of debris as harmless. From our work, it is clear that even small quantities of debris can kill sea turtles by obstructing the gut. Research is needed to determine the extent of absorption of toxins across the gut wall and the consequences of such absorption. Sublethal effects of debris ingestion may have significant effects on the demography of sea turtles.

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