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Impacts of plastic ingestion on post-hatchling loggerhead turtles off South Africa

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ABSTRACT

Twenty-four of 40 (60%) loggerhead turtle *Caretta caretta* post-hatchlings (carapace < 9 cm) that died within 2 months of stranding on southern Cape beaches in April 2015 contained ingested anthropogenic debris. Plastic comprised of 99% of debris: 77% hard plastic fragments, 10% flexible packaging and 8% fibres; industrial pellets comprised only 3%, compared to ~70% in 1968–1973, when 12% of stranded post-hatchlings contained plastics. Turtles selected for white (38%) and blue (19%) items, but translucent items (23%) were under-represented compared to beach mesodebris. Ingested loads did not decrease up to 52 days in captivity, indicating long retention times. Plastic killed 11 turtles by blocking their digestive tracts or bladders, and contributed to the deaths of five other turtles. Our results indicate that the amount and diversity of plastic ingested by post-hatchling loggerhead turtles off South Africa have increased over the last four decades, and now kill some turtles.

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1. Introduction

Marine turtles are arguably the group of marine organisms most at risk from ingesting plastic and other anthropogenic debris (Balazs, 1985; Carr, 1987; Kühn et al., 2015; Nelms et al., 2015). Among most hard-shelled turtles (Cheloniidae), the young, pelagic age classes are more likely to ingest debris (Carr, 1987; Witherington et al., 2012; Schuyler et al., 2014a) and they are susceptible to both intestinal blockage (Santos et al., 2015) and reduced food intake when they eat large amounts of plastic (McCauley and Bjorndal, 1999). However, there are few records of ingestion rates among post-hatchling turtles (<10 cm carapace length) during the first few months of their life at sea (Balazs, 1985; Carr, 1987; Witherington, 1994, 1998, 2002; Boyle and Limpus, 2008).

The first record of plastic ingestion by post-hatchling turtles was from loggerhead turtles *Caretta caretta* that stranded on southern Cape beaches in 1968 (Hughes, 1970) and 1973 (Hughes, 1974a). Of 49 individuals, four (8%) contained plastic pellets and two (4%) contained 'fine plastic sheets' up to 30 × 20 mm. This was less than the incidence of debris in older loggerhead turtles (carapace length 60–70 cm) collected over the same period (44%, n = 9), which ate a greater diversity of debris items, including plastic strips, bags and pieces of glass (Hughes, 1974b). There have been many subsequent records of loggerhead turtles ingesting plastic from around the world (reviewed by Lazar and Gracan, 2011; Schuyler et al., 2014a; Hoarau et al., 2014), but most relate to adults or juveniles with carapaces > 20 cm long. The only data on post-hatchling ingestion are from Florida (Witherington, 1994, 1998, 2002), east Australia (Boyle and Limpus, 2008) and a few animals from the Azores (Frick et al., 2009). Post-hatchling turtles are particularly susceptible to plastic ingestion because they drift at the ocean surface and tend to co-occur with floating seaweed and other debris along drift-lines at downwelling fronts (Carr, 1987; Witherington et al., 2012).

Loggerhead turtle hatchlings leave their breeding beaches in the Mozambique Channel in February/March and are carried south by the Agulhas Current. In most years, small numbers strand along the South African south coast, mainly in late summer (March–May; Hughes, 1970, 1974a). Many of those that are found alive by members of the public are sent to aquariums for rehabilitation. In April–May 2015 an unusually large number of turtles washed ashore along the south coast, some of which died and were examined for ingested marine debris. This provided an opportunity to compare long-term changes in the amounts and types of ingested plastic in stranded post-hatchling turtles in the same region (cf. Hughes, 1970, 1974a). We predicted that, like many seabirds, the importance of plastic pellets among ingested debris in the turtle post-hatchlings would have decreased compared to the 1960s and 1970s, reflecting a decrease in the numbers of pellets at sea, at least compared to other plastic debris types (Vlietstra and Parga, 2002; Ryan, 2008; van Franeker and Law, 2015). By comparing the colours of plastic items recovered from turtles with mesodebris (1–10 mm) collected on beaches along the turtles' dispersal route, we

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were also able to test hypotheses about colour selectivity by post-hatchling turtles (cf. Schuyler et al., 2012). Finally, many turtles were kept in a clean environment at the Two Oceans Aquarium in Cape Town for up to 3.5 months before dying, providing information on the retention time of plastic items in their digestive tracts. Such data are important to better understand temporal and spatial patterns in ingested plastic loads (Ryan, 2015).

2. Materials and methods

The Two Oceans Aquarium in Cape Town received 214 post-hatchling loggerhead turtles (curved carapace lengths < 9 cm, mass < 110 g) that stranded in the Western Cape from mid-March to July 2015, with 95% coming ashore between False Bay (34° 10′S, 18° 28′E) and Arniston (34° 40′S, 20° 12′E) from 1 April to 15 May 2015. Eight turtles died in transit and 36 died in captivity (Table 1). Most post-hatchlings that died (six in transit and 29 after 1–104 days in captivity) were examined to determine the cause of death. Full necropsies were performed and all organs examined, including the gastrointestinal (GI) tract, which was opened up and the contents examined. Plastic items and other anthropogenic debris were recorded visually, and their presence noted in the stomach, intestine, cloaca and bladder (Fig. 1). Debris from 12 of 21 individuals was retained, washed and dried (unfortunately plastic from nine individuals was discarded before counting and measuring). Frozen carcasses of a further 16 loggerhead turtle post-hatchlings that died after stranding in the Eastern Cape during April–May 2015 were obtained from Bayworld Oceanarium in Port Elizabeth. Their digestive tracts were removed and the contents washed through a 300 μm sieve to recover hard prey remains, including marine debris.

At the Two Oceans Aquarium, live turtles being rehabilitated were individually marked and their mass recorded every 1–7 days. Plastic fragments that were observed lodged in the cloacas of live animals were removed with forceps (although some were too firmly wedged to remove) from three turtles that subsequently died, and six that survived; these items were included in analyses of the types of debris ingested, but those from turtles that survived were not used to estimate average plastic loads because necropsy is the most reliable way to estimate ingested debris loads in turtles (Schuyler et al., 2014a, but see Casale et al., 2008). Turtles excrete ingested plastic anything from 6 days to 6 months after ingestion, depending on the size and nature of the plastic item (Lutz, 1990; Schulman and Lutz, 1995; Valente et al., 2008; Hoarau et al., 2014). The large number of hatchlings precluded keeping individuals in separate tanks, which were checked daily and if any plastic was seen it was removed. This limited the risk that turtles re-ingested excreted plastic, but we cannot exclude this possibility. Items removed from dead turtles or the cloacas of live turtles were weighed to the nearest 0.1 mg, measured (length, width and height) with Vernier calipers to the nearest 0.1 mm, and their colour recorded. Finally, all items were placed in seawater to determine whether they floated.

We tested whether ingested plastic load decreased with time in captivity by correlating ingested debris load (number of items and total mass) with time in captivity. Small items might also be easier to excrete (Hoarau et al., 2014), so we tested whether the mean mass of ingested items increased with time in captivity. Two sample t-tests assuming unequal variances were used to test whether fragments of hard plastic removed from the cloaca of live turtles (n = 9) were larger than those recovered during autopsies of dead turtles (n = 16), whether growth rates were influenced by plastic ingestion, as well as whether turtles from the two sample locations differed in size. Growth rates were estimated as the change in body mass per day over the first 30 days in captivity (or a shorter period, if animals died or were released within 30 days). Thirty days was used as an appropriate period over which to estimate growth rates, because absolute daily growth rates accelerated as turtles grew, especially once their mass exceeded 100–150 g.

In order to assess whether turtles differentially ingested particular colours of debris items, we compared the proportions of different colours of debris items ingested by turtles to the frequency of the same types of litter stranded on 72 South African beaches in June–August 2015. Sample beaches were from Muizenberg (34° 06′S 18° 30′E) in False Bay to Cape Vidal (28° 08′S 32° 33′E) on the northeast coast, adjacent to the path post-hatchling turtles follow on leaving their colonies prior to stranding in the southern Cape (Hughes, 1974a). At each beach the top 5 cm of beach sand from a 0.5-m wide transect running up the beach from the most recent high tide line to the storm strand line was sieved through a 2-mm mesh sieve. Plastic items were removed by visual searching, then all remaining items were floated in seawater to detect any items that might have been confused with fragments of shells or stone. Mesodebris items (~2–10 mm) were scored into colour categories by the same observers who scored the items ingested by turtles. Twelve colours were recognized (black, grey, brown, cream, white, clear, yellow, orange, red, green, blue, purple), but several less common colour categories were pooled (black-grey-brown, cream-white, and purple-blue), and red-orange-yellow (wavelengths > 560 nm) were combined because turtle color vision is focused in the shorter wavelengths (450–620 nm; Bartol and Musick, 2003; Schuyler et al., 2014b).

Table 1
Numbers and fate of post-hatchling loggerhead turtles received by the Two Oceans Aquarium for rehabilitation in 2015, with sample sizes for those examined for cause of death, the percentage of these animals containing ingested plastic, and the number for which ingested plastic was retained for quantification and measuring.

	N	Cause of death	% with plastic	Plastic retained
Dead on arrival	8	6	83	2
Died < 2 months of arrival	23	18	83	10
Died > 2 months of arrival	13	11	0	–
Rehabilitated	170	–	4[a]	6[a]
Total	214	35	–	12 (18)

[a] plastic removed from the cloacas of rehabilitated live turtles.

3. Results

The loggerhead turtle post-hatchlings that were sampled had an average curved carapace length of 66 ± 8 mm (SD, range 52–84 mm), with no difference between animals stranding in the Eastern Cape (68 ± 9 mm) and those in the Western Cape (65 ± 8 mm, $t_{30} = 1.08$, $P = 0.29$). Turtles that reached the Two Oceans Aquarium alive weighed 54.8 ± 13.4 g on arrival (26–86 g, n = 32). Ingested debris was found in 4 of 16 (25%) post-hatchlings from the Eastern Cape and 20 turtles that died at the Two Oceans Aquarium; 5 of 6 (83%) that were dead on arrival and 15 of 29 (52%) that died in captivity (Table 1). However, the number ($r^2 = 0.134$, df = 27, $P = 0.05$) and mass ($r^2 = 0.213$, df = 21, $P < 0.05$) of ingested plastic decreased with time in captivity; none of the turtles that died after 2 months in captivity (range 77–104 days) contained plastic (Table 1), suggesting that they may have excreted any ingested plastic prior to death. Among animals that died within 2 months of being in captivity, time to death had no effect on either the number or mass of ingested items ($r^2 = 0.060$, df = 16 and $r^2 = 0.152$, df = 10, respectively); both relationships were weakly positive. The animal with the largest ingested debris load (by number and mass) died after 18 days in captivity, and two individuals that died after 52 days contained the second and third largest loads by mass. Excluding animals that remained in captivity for more than 2 months, 20 of 24 (83%) Western Cape turtles that died contained ingested plastic, significantly more than turtles from the Eastern Cape ($\chi^2 = 11.29$, $P < 0.001$).

The 16 individuals where debris was retained contained 1–61 debris items (dry mass 2–498 mg) per turtle (Table 2, Fig. 1). Unfortunately, because plastic was not retained from nine animals, it was not possible to estimate the average number or mass of debris items per individual across the population. Including three animals where the number of items was recorded on the autopsy notes (n = 1–9 items), the average

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