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Incidence, mass and variety of plastics ingested by Laysan (*Phoebastria immutabilis)* and Black-footed Albatrosses (*P. nigripes*) recovered as by-catch in the North Pacific Ocean

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ABSTRACT

Laysan Albatrosses (*Phoebastria immutabilis*) and Black-footed Albatrosses (*P. nigripes*) ingest plastic debris, as evidenced by studies showing plastic in the digestive contents of their chicks, but there is little documentation of the frequency and amount of ingested plastics carried in foraging adults. In this study, we quantify plastics among the digestive contents of 18 Laysan Albatrosses and 29 Black-footed Albatrosses collected as by-catch in the North Pacific Ocean. We found ingested plastic in 30 of the 47 birds examined, with Laysan Albatrosses exhibiting a greater frequency of plastic ingestion (83.3% $n = 18$) than Black-footed Albatrosses (51.7% $n = 29$) ($X^2 = 4.8$, df = 1, $P = 0.03$). Though the mass of ingested plastic in both species (mean ± SD = 0.463 g ± 1.447) was lower than previously noted among albatross chicks, the high frequency of ingested plastic we found in this study suggests that long-term effects, e.g. absorption of contaminants from plastics, may be of concern throughout the population.

1. Introduction

Plastic debris outweighs the biomass of zooplankton in both near-shore (Moore et al., 2002; Lattin et al., 2004) and offshore (Moore et al., 2001) neuston samples taken from the North Pacific Ocean. Of the 82 species of seabirds known to ingest plastic debris (Ryan, 1990), albatrosses ingest the largest quantities and sizes (Fry et al., 1987; Sileo et al., 1990b). Though potential population level effects of plastic ingestion in albatrosses are still poorly understood, ingested plastics have been shown to cause mechanical damage to the digestive tract through perforation and impaction (Auman et al., 1997; Fry et al., 1987; Pettit et al., 1981; Sievert and Sileo, 1993) and there is evidence of a correlation between greater ingested plastic loads and decreased body condition in albatross chicks (Auman et al., 1997). Plastics can also harbor hydrophobic persistent organic pollutants as well as concentrate pollutants adsorbed from seawater (Endo et al., 2005), and transmit these pollutants to seabirds through ingestion (Teuten et al., 2009). Furthermore, foraging success may decline as plastic is mistaken for prey items in a marine environment containing increasing quantities of plastic (Moore, 2008; Shaw and Day, 1994).

Plastic ingestion in chicks of Laysan and Black-footed Albatrosses has been documented through analysis of regurgitated non-food items in boluses (Pettit et al., 1981; Young et al., 2009), induced emesis (Harrison et al., 1983; Sileo et al., 1990b) and necropsy of deceased chicks (Auman et al., 1997; Fry et al., 1987; Kenyon and Kridler, 1969; Pettit et al., 1981; Sievert and Sileo, 1993; Sileo et al., 1990a,b). Though the high quantity and frequency of ingested plastic in albatross chicks points to frequent ingestion of plastic in foraging adults, there have been few attempts to examine plastic loads in adult and subadult age classes of Laysan and Black-footed Albatrosses (Blight and Burger, 1997; Fry et al., 1987; Harrison et al., 1983; Robards et al., 1997; Sileo et al., 1990b). Given that albatrosses are long lived birds with slow reproductive rates, a better understanding of plastic ingestion in adults is integral to an assessment of potential population level effects. Our study quantifies and compares the incidence, mass and variety of plastic ingested by Laysan Albatrosses and Black-footed Albatrosses foraging in the North Pacific Ocean.

2. Materials and methods

We examined 18 Laysan Albatross and 29 Black-Footed Albatross specimens obtained as by-catch from fisheries near the Hawaiian Islands. While attempting to forage behind fishing vessels, the birds had become impaled on long-line hooks and subsequently drowned. The specimens were collected and frozen by observers from the National Oceanographic and Atmospheric Administration (NOAA) during 2006–2008.

After thawing, the proventriculus and ventriculus (gizzard) were removed from each specimen. Incisions were made as high

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up the esophagus as was possible through the pleural cavity, and directly posterior to the pyloric sphincter. The mouth and upper esophagus were inspected, and contents were extracted and included in the proventricular sample. The proventriculus and ventriculus were opened using a single incision running from the remaining esophagus down through the proventriculus and ventriculus. The contents of each and were scooped into tray and weighed to the nearest 0.001 g.

Digestive contents were sorted manually and plastics were removed using visual identification aided by the use of a dissecting microscope. All plastics were rinsed in water, air dried overnight, weighed to the nearest 0.001 g, and the maximum dimension was measured to the nearest 1 mm. Plastics were categorized as: (1) fragments (any piece of plastic from a larger object that was not determined to be line or foam), (2) industrial pellet (thermoplastic resin feedstock), (3) line (including monofilament, braided poly-line, synthetic yarn, and string); or (4) foam (expanded polystyrene or polyurethane).

3. Results

Thirty of 47 albatross specimens (63.8%) contained ingested plastic. Laysan Albatrosses ($n = 18$) had a higher frequency, 83.3% of ingested plastic than Black-footed Albatrosses, 51.7% ($n = 29$) (chi-square test of independence $X^2 = 4.8$, df = 1, $P = 0.028$; Table 1).

At 0.998 g ± 2.244, Laysan Albatross specimens exhibited a higher mean mass of ingested plastic than the 0.134 g ± 0.291 for Black-footed Albatrosses (Mann–Whitney U test, $U = 174$, $P = 0.0575$). The maximum mass of ingested plastic found in an individual was 8.124 g, recovered from a Laysan Albatross, while the Black-footed Albatross maximum was 1.085 g. Five of the 47 specimens had more than 1 g of plastic, however the median of 0.004 g of plastic indicates that most individuals had much less plastic than the mean value (Table 1).

Of the four varieties of plastic, fragments contributed the greatest mean mass in both species and the highest incidence in Laysan Albatrosses (Table 2). Between the species, Laysan Albatross specimens contained a higher mean mass of fragments, and Black-footed Albatross specimens contained a higher mean mass of line (Table 2). Line was often found entwined in masses of fish eggs, and of the 9 Black-footed Albatrosses that contained line, 8 also contained fish eggs (compared to the average 62% with fish eggs overall; Table 1). Only 11.1% of the Laysan Albatrosses ($n = 18$) contained fish eggs (Table 1) and plastic line was also far less prevalent in this species (Table 2). The maximum number of plastic pieces recovered from a single specimen was 139, found in a Black-footed Albatross; 135 of these were line.

Table 2
Mass, count, and frequency of occurrence (FO) of different varieties of plastic recovered from the digestive contents of Laysan Albatrosses and Black-footed Albatrosses found to contain ingested plastic.

	Mass (g) x ± SD	Count (#) x ± SD	%FO
Laysan Albatross ($n = 15$)			
Fragments	1.162 ± 2.436	4.8 ± 5.23	80.0
Line	0.002 ± 0.005	1.0 ± 2.00	33.3
Pellets	0.010 ± 0.024	0.4 ± 1.06	20.0
Foam	0.001 ± 0.003	0.3 ± 1.03	6.7
Black-footed Albatross ($n = 15$)			
Fragments	0.186 ± 0.293	3.8 ± 5.95	53.3
Line	0.070 ± 0.209	16.7 ± 36.17	53.3
Pellets	0.002 ± 0.007	0.1 ± 0.26	6.7
Foam	0.001 ± 0.004	0.1 ± 0.13	6.7

4. Discussion

The high incidence of ingested plastic observed in both Laysan and Black-footed specimens indicates adults of both species of albatrosses are exposed and that any detrimental effects from plastic ingestion may be far reaching. The high incidence of plastic ingestion found in this study is consistent with that observed in a similar study on by-catch specimens of the same species in the central North Pacific (Laysan Albatross 93%, $n = 167$, Black Footed Albatross 45%, $n = 110$; Robards et al., 1997). Of the two species, the higher incidence and mean mass of plastic in Laysan Albatrosses was also consistent with the findings of Robards et al. (1997), suggesting this species may be at greater risk from any harmful effects caused by ingested plastic. However, further research would be required to exclude bias introduced by seasonal and annual foraging trends and the use of by-catch specimens to confirm the variations we noted between species.

Of the four varieties of plastics recovered in this study, the dominance (by mean mass) of fragments indicates that both Laysan and Black-footed Albatrosses are primarily ingesting plastics composed of a variety of degraded post-consumer products. Between the two species, Laysan Albatrosses had a higher mean mass of fragments and Black-footed Albatrosses had a higher mean mass of line. The higher average mass of line we found in Black-footed Albatrosses is consistent with the findings of Sileo et al. (1990b). This suggests that Black-footed Albatrosses ingest more fishing industry by-products than Laysan Albatrosses. The greater mass and

Table 1
Mass and frequency of occurrence (FO) of plastic and digestive contents in the proventriculus and ventriculus of Laysan Albatrosses (LAAL) and Black-footed Albatrosses (BFAL) and of both species combined (B) in the North Pacific Ocean, 2006–2008.

	LAAL ($n = 18$)	BFAL ($n = 29$)	B ($n = 47$)
Mass of plastic (g)			
Total x ± SD	0.998 ± 2.244	0.130 ± 0.286	0.463 ± 1.447
Median	0.127	0	0.004
Maximum	8.124	1.085	8.124
% FO of ingested plastic	83.3	51.7	61.7
Mass of digestive contents (g)			
Total x ± SD	57.396 ± 93.358	53.405 ± 96.496	54.880 ± 94.322
Median	16.456	16.575	16.516
Maximum	369.316	418.762	418.762
% FO of prey			
Squid	94.4	89.7	91.5
Fish	38.9	41.4	40.4
Fish eggs	11.1	62.0	42.6
Arthropods	16.7 (crustaceans.)	6.9 (Halobates sp.)	10.6
%FO of pumice	16.7	0	6.4

incidence of line in the digestive contents of Black-footed Albatrosses was coincident with the higher incidence of fish eggs (Table 1), which we often found attached to plastic line, in their diet. This association was previously reported by Harrison et al. (1983).

The mass of foam and industrial pellets recovered in this study was minimal. Contrarily, Blight and Burger (1997) found industrial pellets made up about half of the plastic pieces recovered from three Black-footed Albatrosses obtained as by-catch. However, their sample was collected in the eastern North Pacific off British Columbia, Washington and Oregon.

The high incidence of ingested plastic found in Laysan Albatrosses was lower than values previously reported for Laysan Albatross chicks (Auman et al., 1997; Young et al., 2009). A trend of greater incidence of ingested plastics in Laysan Albatross chicks than in adults was also observed by Sileo et al. (1990b). The greatest mass of ingested plastic (8.124 g) recovered from an individual in this study was about half of the mean mass previously found in Laysan Albatross chicks (15.7 g, $n = 251$; Auman et al., 1997). Blight and Burger (1997) also found adult albatrosses to be carrying a lower mean mass of plastic than that reported for chicks, though their sample was limited to 3 adult Black-footed Albatrosses. If the mass of ingested plastic we recorded represents that carried by foraging albatrosses in the North Pacific Ocean, load dependent effects of plastic ingestion, such as impaction or displacement of prey items, would more likely occur in their chicks. However, the low median mass of digestive contents (Table 1) raises questions about use of by-catch specimens to quantify plastic ingestion. Potential sources of bias in our sample include; loss of ingested items due to regurgitation upon entanglement with fishing gear, and altered foraging behavior caused by interaction with fishing vessels (Bison, 2008; Hyrenbach, 2001). We noted signs of regurgitation e.g. diet contents in the esophagus and mouth, in several specimens during necropsy. We also found the diet contents of several specimens to be primarily composed of cut or dyed pieces of bait fish. Further research is required to determine if specimens obtained through fisheries by-catch result in underestimates of plastic burdens in these species.

To better understand long-term effects of plastic ingestion on albatross populations, ongoing monitoring efforts will be required. Unfortunately, disparate research methodology provides little comparable data to analyze ongoing trends within populations of Black-footed Albatrosses and Laysan Albatrosses. A unified approach for assessing long-term impacts of plastic ingestion is needed.

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