Marine Pollution Bulletin 56 (2008) 1406–1409

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Seabirds indicate changes in the composition of plastic litter in the Atlantic and south-western Indian Oceans

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ARTICLE INFO

Keywords:
Plastic ingestion
Seabirds
Virgin pellets
Tristan da Cunha
South Africa
Atlantic Ocean
Western Indian Ocean

ABSTRACT

I compare plastic ingested by five species of seabirds sampled in the 1980s and again in 1999–2006. The numbers of ingested plastic particles have not changed significantly, but the proportion of virgin pellets has decreased 44–79% in all five species: great shearwater *Puffinus gravis*, white-chinned petrel *Procellaria aequinoctialis*, broad-billed prion *Pachyptila vittata*, white-faced storm petrel *Pelagodroma marina* and white-bellied storm petrel *Fregetta grallaria*. The populations sampled range widely in the South Atlantic and western Indian Oceans. The most marked reduction occurred in great shearwaters, where the average number of pellets per bird decreased from 10.5 to 1.6. This species migrates between the South and North Atlantic each year. Similar decreases in virgin pellets have been recorded in short-tailed shearwaters *Puffinus tenuirostris* in the Pacific Ocean and northern fulmars *Fulmarus glacialis* in the North Sea. More data are needed on the relationship between plastic loads in seabirds and the density of plastic at sea in their foraging areas, but the consistent decrease in pellets in birds suggests there has been a global change in the composition of small plastic debris at sea over the last two decades.

1. Introduction

Floating plastic litter is one of the most widespread and abundant marine pollutants (Coe and Rogers, 1997; Derraik, 2002). It is eaten by a wide range of marine organisms, including seabirds, marine mammals, turtles and fish (Laist, 1997), reducing effective stomach volume (Ryan, 1988a), introducing toxic chemicals (Ryan et al., 1988; Mato et al., 2001) and, in severe cases, blocking the digestive tract (Fry et al., 1987; Derraik, 2002). Surface and shallow-diving seabirds are especially prone to eating plastic debris, with petrels and storm petrels accumulating large loads in their stomachs due to their inability to pass them through the pyloric sphincter into the intestine (Furness, 1985). The size of plastic articles ingested is related to bird size; larger birds eat larger items (Furness, 1985; Ryan, 1987). Initial studies of plastic ingestion found that most plastics ingested by small and medium-sized seabirds were virgin, industrial plastic pellets (Day et al., 1985; Ryan, 1987; Laist, 1997). These small beads, 1–5 mm across, are the primary feedstock of the plastics industry. Spilled pellets are carried in waste water, accumulating at sea where they are long lived and disperse far from source areas (Gregory and Ryan, 1997). First reported in prions *Pachyptila* spp. in New Zealand in 1960 (Harper and Fowler, 1987), pellets were reported in large numbers at sea off eastern North America in the early 1970s (Carpenter and Smith, 1972; Colton et al., 1974), and are now ubiquitous throughout the world's oceans (e.g. Robards et al., 1997; Moore et al., 2001).

In the early 1990s, the plastics industry established education programmes (e.g. Operation Clean Sweep, see www.opcleansweep.org) to prevent the loss of pellets. There are few data to demonstrate the efficacy of this initiative. Semi-quantitative surveys in New Zealand and islands in Oceania suggest that the numbers of pellets on beaches decreased in the early 1990s (Gregory and Ryan, 1997). Short-tailed shearwaters *Puffinus tenuirostris* sampled in the North Pacific in the late 1990s contained similar plastic loads to those sampled in the late 1970s, but the proportion of virgin pellets had decreased from 55–73% to 33% (Vlietstra and Parga, 2002). More recently, a long term decrease has been recorded in the mass of virgin pellets in northern fulmars *Fulmarus glacialis* stranded on Dutch beaches over the last 20 years (van Franeker et al., 2005). In this study, I report decreases in the numbers of virgin pellets in five species of seabirds that range widely in the Atlantic and south-west Indian Oceans, and discuss whether this indicates that there has been a decrease in the numbers of pellets at sea.

2. Methods

I obtained ingested plastics from seabirds either by dissecting dead birds to examine their stomach contents (Ryan, 1987), or by finding plastics in regurgitations of Subantarctic skuas *Catharacta antarctica* roosting at Inaccessible Island, Tristan da Cunha, central

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doi:10.1016/j.marpolbul.2008.05.004

South Atlantic Ocean (Ryan and Fraser, 1988). Skuas regurgitate the bones, feathers and other indigestible remains of birds they eat (Ryan and Moloney, 1991). I collected skua regurgitations from a large skua roost at West Point, Inaccessible Island, in 1987, 1988, 1989/90, 1999/2000 and 2004. Plastics from regurgitations collected in 1982 (Ryan and Fraser, 1988) were ignored because subsequent samples indicated observer bias in the detection of small plastic fragments. All samples reported in this study were collected by the same observer. Some skua pellets contain the remains of two or three birds; I only collected plastics from pellets containing a single avian prey item. For this analysis, I restricted comparisons to samples collected in October–November, prior to the large chick stage for each species, to remove the effect of inter-generational transfer of plastic (Ryan, 1988b). Three species were eaten in sufficient numbers to provide adequate samples for comparisons of trends in the amount and composition of ingested plastic: broad-billed prion *Pachyptila vittata*, white-faced storm petrel *Pelagodroma marina* and white-bellied storm petrel *Fregetta grallaria*.

Data from white-chinned petrels *Procellaria aequinoctialis* and great shearwaters *Puffinus gravis* in the 1980s were taken from Ryan (1987). For white-chinned petrels, I only used data from fully-grown birds collected for diet studies in the Benguela region off South Africa (Jackson, 1988), which were compared with birds killed accidentally on long-lines in South African waters during 2005–2006. Most great shearwaters in the 1980s were breeding adults collected at Gough Island in November 1984 ($n = 30$), with a few collected at sea off South Africa. These were compared with a sample of breeding adults collected on Nightingale Island, Tristan da Cunha, in November 2005 as part of a subsistence harvesting programme ($n = 50$). I also included a few birds killed on long-lines off South Africa in October 2005.

I removed all plastic items from stomach and gizzard contents, counted and sorted them into virgin pellets and user plastics (all non-pellet, secondary articles, including fibres and fragments of bags). Changes in the proportions of pellets and user plastics were tested with chi-squared goodness of fit tests, using Yate's correction for continuity where necessary. Changes in the numbers of plastic items in each species over time were tested with Student *t*-tests or ANOVA after testing for equal variances. Plastics from skua regurgitations collected in the 1980s were pooled after recording the total number per bird and only later categorised, limiting comparisons to changes in total plastic load and the overall proportion of pellets.

Table 1
Changes in ingested plastic in seabirds sampled in the South Atlantic Ocean

Species	1983–85	2005/06	Significance
Great shearwater			
Sample size	33 (538)	53 (624)	
All ingested plastic	16.3 ± 19.0	11.8 ± 18.9	$t_{68} = 1.08$, $P = 0.29$
Virgin pellets	10.5 ± 14.1	1.6 ± 3.5	$t_{35} = 3.54$, $P < 0.001$
User plastics	5.8 ± 7.3	10.1 ± 17.4	$t_{76} = 1.59$, $P = 0.12$
% Plastic pellets	64.3%	11.3%	$\chi^2_1 = 311.4$, $P < 0.001$
White-chinned petrel			
Sample size	193 (321)	526 (780)	
All ingested plastic	1.66 ± 3.04	1.39 ± 3.25	$t_{353} = 1.07$, $P = 0.29$
Virgin pellets	0.64 ± 1.20	0.22 ± 0.88	$t_{266} = 4.40$, $P < 0.001$
User plastics	1.02 ± 2.20	1.16 ± 2.76	$t_{416} = 0.70$, $P = 0.48$
% Plastic pellets	38.3%	16.2%	$\chi^2_1 = 62.6$, $P < 0.001$

Sample size gives the numbers of birds sampled and the total number of plastic items ingested (in parentheses).

3. Results

Plastic loads were recorded for more than 2000 seabirds: 946 in the 1980s and 1128 in 1999–2006 (Tables 1 and 2). The most remarkable change occurred in great shearwaters, where the average number of pellets decreased by almost an order of magnitude from the 1980s to 2005/06 (Table 1). This decrease was partly offset by an increase in the average number of user items, which doubled over the same period, but the difference was not significant due to large variances among birds. Total plastic loads decreased, but again this was not significant (Table 1). White-chinned petrels contained fewer ingested plastics than great shearwaters, and the change in the numbers of pellets was more modest. However, there was still almost a three-fold decrease in the average numbers of pellets per bird over the last two decades, whereas there was a small increase in the average number of user items (Table 1).

Analysis of skua pellets indicated that the proportions of pellets in all three petrels breeding at Inaccessible Island decreased from the late 1980s to 1999 and again to 2004 (Fig. 1), while the total amount of plastic ingested remained constant (Table 2). Although individual pellet loads were not recorded, the average load per bird decreased for all three species from the late 1980s to 1999–2004: white-faced storm petrels decreased from 2.78 to 1.09 pellets per bird, white-bellied storm petrels from 0.21 to 0.13, and broad-billed prions from 0.75 to 0.69.

4. Discussion

Seabirds can be sensitive monitors of small plastic litter at sea. Previous studies have shown long-term trends in the amount of ingested plastic (e.g. Harper and Fowler, 1987; Moser and Lee, 1992; Robards et al., 1995) as well as regional differences in plastic loads

Table 2
Changes in ingested plastic in seabirds killed by Subantarctic skuas at Inaccessible Island (mean ± SD plastic items per bird and percentage plastic pellets)

Species	1987–89	1999	2004	Significance
White-faced storm petrel				
Sample size	253 (1008)	86 (349)	50 (126)	
Plastic ingested	3.98 ± 5.45	4.06 ± 5.93	2.52 ± 4.43	$F_{2,386} = 1.56$, $P = 0.21$
% virgin pellets	69.6%	37.5%	13.5%	$\chi^2_2 = 217.3$, $P < 0.001$
White-bellied storm petrel				
Sample size	318 (201)	137 (86)	95 (68)	
Plastic ingested	0.63 ± 1.13	0.63 ± 1.37	0.72 ± 1.87	$F_{2,547} = 0.16$, $P = 0.85$
% Virgin pellets	33.3%	20.9%	16.2%	$\chi^2_2 = 9.73$, $P < 0.01$
Broad-billed prion				
Sample size	149 (257)	86 (252)	95 (253)	
Plastic ingested	1.73 ± 3.58	2.93 ± 3.80	2.66 ± 5.34	$F_{2,327} = 2.70$, $P = 0.07$
% Virgin pellets	43.6%	33.7%	15.4%	$\chi^2_2 = 48.7$, $P < 0.001$

Sample size gives the numbers of birds sampled and the total number of plastic items ingested (in parentheses).