Marine Pollution Bulletin 114 (2017) 699–704

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Anthropogenic debris in the nests of kelp gulls in South Africa

Minke Witteveen [a,*], Mark Brown [b], Peter G. Ryan [a]

[a] Percy FitzPatrick Institute of African Ornithology, DST-NRF Centre of Excellence, University of Cape Town, Private Bag X3, Rondebosch 7701, South Africa
[b] School of Life Sciences, University of KwaZulu-Natal, Private Bag X01, Scottsville 3209, South Africa

ARTICLE INFO

Article history:
Received 7 September 2016
Received in revised form 18 October 2016
Accepted 19 October 2016
Available online 27 October 2016

Keywords:
Entanglement
Nest lining
Plastics
Regurgitation
Waste management
Larus dominicanus

ABSTRACT

Anthropogenic debris results in detrimental interactions with many marine species. Several seabirds include debris items in their nests, which can lead to entanglement of chicks and adults, resulting in injury or death. Anthropogenic debris was found in 4–67% of kelp gull *Larus dominicanus* nests in seven colonies in the Western Cape, South Africa. Nests contained two types of litter: items included in the nest structure during construction (mainly ropes and straps), and regurgitated items (mainly bags and food wrappers) that probably accumulate primarily during the chick-rearing period. Debris used in nest construction was more likely to injure gulls, and was found mainly at coastal sites where there was little natural vegetation for construction. Distance to the nearest urban waste landfill significantly affected the occurrence of debris items in nests, especially dietary-derived items. The amount of debris in kelp gull nests highlights the need for improved debris management in South Africa.

1. Introduction

The effects of anthropogenic debris on marine and coastal environments have received much attention lately, especially the impacts of plastic debris (Bergmann et al., 2015). Due to the increasing abundance of anthropogenic debris in marine systems, species are increasingly likely to interact with it, often to their detriment (Derraik, 2002; Laist, 1987, 1997). A variety of marine mammals, birds, turtles and fish species are negatively affected by interactions with marine debris, with the number of species and individuals affected increasing since the early 1960s (Barnes et al., 2009; Derraik, 2002; Gregory, 2009; Kühn et al., 2015; Laist, 1997; Ryan et al., 2009). For these marine vertebrates, the major interactions are entanglement and ingestion, and the likelihood of entanglement or ingestion is exacerbated by behavioural patterns (Derraik, 2002; Laist, 1987, 1997). For seabirds, the presence of anthropogenic debris in their nests can increase the risk of entanglement, but this issue has only recently received increased attention (Bond et al., 2012; Clemens and Hartwig, 1993; Hartwig et al., 2007; Lavers et al., 2013; Lee et al., 2015; Petersen et al., 2016; Provencher et al., 2014; Verlis et al., 2014; Votier et al., 2011).

Anthropogenic debris in nests poses an entanglement threat to both parents and chicks, potentially reducing breeding success (Votier et al., 2011). Debris items have been found in a number of marine birds' nests including albatrosses (Diomedeidae, Nel and Nel, 1999), boobies and gannets (Sulidae, Bond et al., 2012; Lavers et al., 2013; Montevecchi, 1991; Norman et al., 1995; Ostrowski et al., 2005; Tavares et al., 2016; Verlis et al., 2014; Votier et al., 2011), cormorants (Phalacrocoracidae, Podolsky and Kress, 1989), kittiwakes (*Rissa*, Hartwig et al., 2007), and terns (Sterninae, Petersen et al., 2016). It also occurs in the nests of some waterbirds, such as spoonbills (*Platalea*, Lee et al., 2015). Considering how well adapted to urbanisation gulls are (Duhem et al., 2008; Lisnizer et al., 2011; Yorio and Borboroglu, 2002), it is surprising that there is little published literature on the presence of anthropogenic debris in gull nests. Apart from studies on black-legged kittiwakes (*Rissa tridactyla*) (Clemens and Hartwig, 1993; Hartwig et al., 2007), there are only some ad hoc observations for black-headed (*Chroicocephalus ridibundus*) and herring gulls (*Larus argentatus*) (Hartwig et al., 2007).

Most birds incorporate debris items in their nests because they select them for nest construction. The likelihood of so doing depends in part on the availability of natural materials close to the nest site. Brown boobies *Sula leucogaster* nesting in the open use more marine debris in their nests than those breeding in well-vegetated areas (Lavers et al., 2013), and providing additional natural nesting material decreases the amount of debris in black-faced spoonbill *Platalea minor* nests (Lee et al., 2015). Like most gulls, kelp gulls *Larus dominicanus* nest in a scrape on the ground or among low vegetation (Crawford and Hockey, 2005). In open habitats, such as coastal dunes, they gather items from surrounding areas (vegetation, kelp, shells, feathers, litter) to form the outer walls of the nest, but in vegetated areas there is less attempt to gather materials, with the scrape being formed among vegetation which creates the outer rim of the nest (Crawford and Hockey, 2005). As a result, the amount of debris used for construction is likely to vary depending on colony location and microhabitat within the colony. However, gulls also eat and then regurgitate indigestible items, including

* Corresponding author.
E-mail addresses: minke.witteveen@gmail.com (M. Witteveen), brownma@ukzn.ac.za (M. Brown), peter.ryan@uct.ac.za (P.G. Ryan).

http://dx.doi.org/10.1016/j.marpolbul.2016.10.052
0025-326X/

plastics and other anthropogenic debris (Ryan, 1987). As a result, some nest debris could derive from regurgitations from adults or chicks. In this case, the amount of nest debris indicates the likelihood of debris ingestion, and is expected to be greater close to urban areas where many gulls scavenge on human refuse.

We compare the amounts of debris in kelp gull nests to infer the sources of different debris types, and the factors responsible for gulls including debris in their nests. We compare debris in nests at coastal sites with inland sites to test the hypothesis that debris used for nest construction should be more frequent at coastal sites, where gulls have access to stranded beach litter. We also expect that within coastal sites, debris should be more abundant in nests in open habitats where there is less natural material to use for nest construction. To identify which types of debris are derived from the diet rather than selected for nest construction, we collected debris from an inland gull colony in a remote mountain wilderness area closed to human access. This colony is so remote that any debris present derives from the gulls' diet. We hypothesise that the abundance of dietary litter in gull nests should decrease with distance from urban source areas, specifically from waste landfill sites.

2. Methods

2.1. Study sites

Nests in seven kelp gull breeding colonies in the Western Cape, South Africa, were examined for anthropogenic debris (Fig. 1). Four colonies were in coastal dune systems where they had ready access to stranded marine debris: Strandfontein (34°05.5′S 18°31.9′E), De Mond (34°42.1′S 20°08.9′E), Robberg Island (34°06.5′S, 23°23.2′E), and Keurbooms Estuary (34°02.4′S, 23°23.1′E); and three colonies were further inland: two were on salt pans without marine litter: Dwarskersbos (32°43.7′S 18°12.2′E) and Yzerfontein (33°19.9′S 18°09.8′E); and one was in a remote area of mountain fynbos, 350 m above sea level adjacent to Steenbras Dam (34°11.4′S 18°52.6′E). Colonies differed in distance to nearest urban waste landfill: the Strandfontein colony is only 2.7 km from an urban waste landfill, Robberg Island 4.2 km, Keurbooms Estuary 6.0 km, De Mond 21.1 km, Dwarskersbos 25.4 km, Yzerfontein 30.9 km, and Steenbras Dam the most remote at 36.2 km from a landfill site.

2.2. Data collection

Each breeding colony was visited towards the end of the breeding season (6–26 December 2013), by which time it was expected that pairs at most colonies would be provisioning large chicks. This was the case at all but one of the colonies. Only one pair had chicks at De Mond while all other pairs were incubating eggs (probably replacement clutches following early breeding failures due to natural predation pressure). Disturbance within each colony was kept to a minimum by sampling late in the breeding season, and by working quickly and quietly. At each colony, all anthropogenic debris was collected from a sample of 40–211 nests. Transects were walked through the colonies and all nests examined for debris. Any debris items found were collected and bagged separately for each nest. At the time of debris collection most nests contained large chicks, which moved away from the nest area. Debris items were removed carefully to maintain nest integrity. The colony at Steenbras Dam was in a remote reserve area closed to human visitors; no litter was found in areas surrounding the breeding colony, so all litter within the colony (lying between/surrounding nests) was collected as it was almost certainly carried to the site by gulls.

At coastal dune sites each nest was classified as open or vegetated based on the surrounding vegetation available for nest building. At De Mond, two breeding groups were sampled: the main group, 2.5 km east of the river mouth was on open dunes behind the beach with only marine debris (seaweed and litter) available for nest construction in the immediate vicinity, whereas a smaller group at the river mouth had access to vegetation deposited by the river (mainly Cape eelgrass *Zostera capensis*) for nest material. At the Keurbooms Estuary, two breeding groups separated by the river mouth were sampled: the main group on Keurbooms Peninsula has most nests in dense groundcover, whereas the smaller group on Lookout Beach has nests in pockets of vegetation; both had access to similar nest material. All nests at Steenbras Dam were among vegetation, but nests at the two

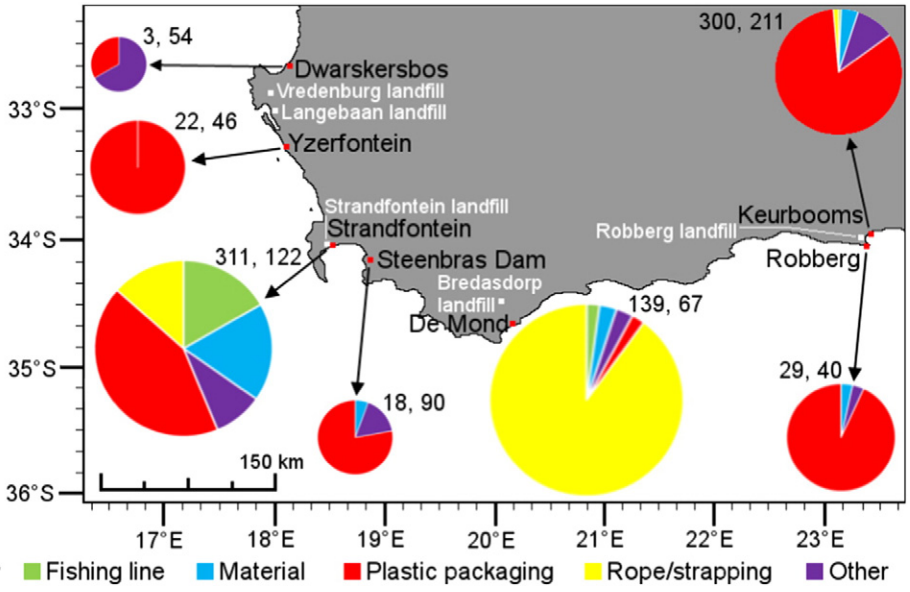

Fig. 1. Site-specific variation in the occurrence of anthropogenic debris items in kelp gull nests in the Western Cape, South Africa. De Mond was surveyed during incubation whereas other locations were provisioning large chicks. Numbers adjacent to pie charts give total items collected and total nests surveyed at each location, respectively. Pie charts are scaled to the proportion of nests containing anthropogenic debris.

salt pan colonies (Dwarskersbos and Yzerfontein) occurred in a variety of sites ranging from bare, open ground to dense ground cover.

Debris items collected were identified in terms of type of material and function, and grouped into the following categories: fishing line (monofilament line and hooks), flexible plastic packaging (cling wrap, carrier bags, other bags and food wrapping), ropes and plastic strapping (including some ropes used by fisheries), material (wet wipes, hairnets, clothing scraps), and other items (tinfoil, foamed plastics, cigarette butts, paper, etc.). Item length, width, and mass (dry mass to the nearest 0.1 g) were recorded. Flexible items were untangled and straightened to measure their maximum dimensions.

At Robberg Island and Keurbooms Estuary pellets regurgitated by adult kelp gulls were collected opportunistically during the 2013/14 breeding season, only some of which corresponded to an active nest and known breeding stage, thus pellets from both incubation and chick provisioning were pooled. Pellets were frozen at −20 °C until analysis. After defrosting, pellets were soaked in water and dissected to identify all anthropogenic items.

2.3. Statistical analyses

All statistics were analysed using R (version 3.2.3, R Foundation for Statistical Computing 2015). Values are reported as means ± 1 SD. The effect of nest type (vegetated/open), location type (coastal dune/inland) and distance to nearest urban waste landfill (used as a proxy for location as these two variables are collinear) on the occurrence of anthropogenic debris items in kelp gull nests (overall and by debris categories) was tested using a generalised linear model (GLM) with a binomial distribution and logit link function. Models were compared using the aictab function in the AICcmodavg package, and the most influential models were selected based on Akaike's information criterion corrected for a small sample size (AICc values; Burnham and Anderson, 2002). Models with substantial support (ΔAICc < 4) were averaged using the model.avg function in the MuMIn package (Multimodel Inference). Presence/absence comparisons were performed using a two-sample test for equality of proportions with continuity correction (prop.test function in R).

A GLM with poisson distribution and log link function was used to determine the influence of nest type, location type, and distance to the nearest urban waste landfill on the number of anthropogenic debris items found in each nest. After detecting over-dispersion, a GLM with a negative binomial distribution and log link function was used from the MASS package (Support Functions and Datasets for Venables and Ripley's MASS). Model AIC weights were calculated using the Weights function in MuMIn. The most influential models were selected based on AIC values, and averaged with model.avg. *t*-Tests were used to determine significant differences in the number of anthropogenic debris items between levels of categorical variables. Results from statistical analyses were taken to be significant at the 0.05 level.

3. Results

Anthropogenic debris items were found in kelp gull nests at all colonies, with the frequency of occurrence ranging from 4 to 67%. Within sites, the frequency of occurrence of debris items varied according to whether nests were in vegetated areas (range 4–44%), or open areas (range 11–82%) which lacked natural items for nest construction (Table 1). The number of items in vegetated nests averaged from 0.2–1.8 items per colony (mass 0.2–0.7 g, maximum 26 items, 8.0 g), whereas open nests averaged 0.3–3.4 items (0.3–1.5 g, maximum 19 items, 15.8 g; Table 1). Although debris items were found in nests at all seven colonies surveyed, plastic packaging was the only type of debris collected from every site (Table 2, Fig. 1). Fishing line and rope/strapping occurred least commonly, being found in nests from only three of the seven colonies (Table 2, Fig. 1). On average, fishing line was the longest item type occurring in nests, while items from the 'other' debris type (tinfoil, foamed plastics, cigarette butts, paper) were the shortest (Table 2).

Debris items collected from nests at Steenbras Dam were of a similar composition, although smaller in size, to items found away from nests within the breeding colony (Table 2). Only three types of debris (material, plastic packaging, and other) were collected from nests at this colony. These debris types were assumed to be derived from the gulls' diet, because this colony is in a remote mountain wilderness area lacking local sources of debris for use in nest construction. Plastic packaging and other debris items were regularly recorded in pellets regurgitated by gulls at other colonies (Table 3).

The best fitting models explaining the frequency of occurrence of anthropogenic debris in kelp gull nests contained all three explanatory variables: nest type, location type, and distance to nearest urban waste landfill (Supplemental Table 1). The frequency of occurrence of all debris items varied significantly according to distance to nearest urban waste landfill and location type (Supplemental Table 2). Debris items decreased with increasing distance from the nearest urban waste landfill (Supplemental Fig. 1a). Coastal breeding colonies had a higher frequency of occurrence of anthropogenic debris items (47%) than inland colonies (13%; $\chi^2 = 65.55$, d.f. = 1, $p < 0.001$).

When considering the effect of distance to nearest urban waste landfill, nest type, and location type on the frequency of occurrence of each of the five debris types collected, there was only one best fitting model for rope/strapping, while the other debris types had more than one model with substantial support (ΔAICc < 4; Supplemental Table 3). Of the three explanatory variables tested, distance to the nearest urban waste landfill had a consistent significant effect on all five debris types, with less litter in nests at colonies far from landfill sites (Supplemental Table 4; Supplemental Fig. 1b–f). Nest type had a significant effect on four debris types (Supplemental Table 4), with open nests more likely to contain fishing line (16% vs 1%; $\chi^2 = 32.25$, d.f. = 1, $p < 0.001$), material (15% vs 5%; $\chi^2 = 15.40$, d.f. = 1, $p < 0.001$), and rope/strapping

Table 1
The occurrence and quantity of anthropogenic debris items found in kelp gull nests in the Western Cape, South Africa.

Location	Nest type (n nests)	Frequency of occurrence (%)	Avg number of items/nest ± SD (maximum)	Avg mass items/nest ± SD (g) (maximum)
Strandfontein	Open (60)	82	3.4 ± 3.4 (19)	0.8 ± 1.0 (5.3)
Strandfontein	Vegetated (62)	40	1.7 ± 3.2 (15)	0.5 ± 0.8 (3.0)
De Mond	Open beach (37)	78	3.1 ± 2.5 (10)	1.5 ± 1.5 (6.6)
De Mond	Open estuary (30)	53	0.9 ± 1.0 (3)	1.3 ± 3.1 (15.8)
Robberg	Open (6)	17	0.3 ± 0.8 (2)	0.3 ± 0.6 (1.5)
Robberg	Vegetated (34)	32	0.8 ± 1.5 (6)	0.6 ± 1.1 (5.0)
Keurbooms	Open (53)	11	0.3 ± 0.8 (3)	0.3 ± 1.1 (5.8)
Keurbooms	Vegetated (158)	44	1.8 ± 3.6 (26)	0.7 ± 1.2 (8.0)
Dwarskerbos	Open/vegetated (54)	4	0.1 ± 0.3 (2)	0.1 ± 0.3 (1.8)
Yzerfontein	Open/vegetated (46)	22	0.5 ± 1.1 (5)	0.7 ± 1.6 (5.6)
Steenbras Dam	Vegetated (90)	13	0.2 ± 0.6 (3)	0.2 ± 0.6 (3.4)

Table 2
Size and mass (mean ± SD) of anthropogenic debris items collected from kelp gull nests at seven locations in the Western Cape.

Debris type		Location (number of nests surveyed)							
		Strandfontein (122)	De Mond (67)	Robberg Island (40)	Keurbooms (211)	Dwarskersbos (54)	Yzerfontein (46)	Steenbras Dam (90)	Steenbras general[a]
Fishing line	n items (nests)	51 (28)	3 (2)	–	1 (1)	–	–	–	–
	Length (cm)	62.7 ± 46.6	36.7 ± 28.9	–	37.0	–	–	–	–
	Width (cm)	0.1 ± 0.0	0.1 ± 0.1	–	0.1	–	–	–	–
	Weight (g)	0.3 ± 0.5	0.7 ± 1.0	–	0.2	–	–	–	–
Material	n items (nests)	56 (32)	4 (3)	1 (1)	13 (12)	–	–	1 (1)	3
	Length (cm)	18.1 ± 17.8	48.5 ± 27.9	25.0	14.0 ± 10.0	–	–	20.9	25.7 ± 9.0
	Width (cm)	4.7 ± 4.1	1.4 ± 0.8	4.0	4.3 ± 4.4	–	–	20.9	15.7 ± 10.7
	Weight (g)	1.4 ± 1.8	6.4 ± 11.3	2.4	1.5 ± 2.0	–	–	4.6	15.0 ± 8.4
Plastic packaging	n items (nests)	133 (53)	3 (2)	27 (12)	253 (72)	1 (1)	22 (10)	14 (11)	70
	Length (cm)	20.1 ± 12.0	19.8 ± 3.3	12.5 ± 8.7	18.1 ± 10.6	25.0	24.0 ± 10.0	20.0 ± 11.6	25.4 ± 14.8
	Width (cm)	6.9 ± 7.1	3.0 ± 1.7	2.5 ± 1.4	5.9 ± 13.8	7.0	10.3 ± 8.1	4.6 ± 3.0	9.1 ± 5.5
	Weight (g)	1.3 ± 1.5	3.2 ± 3.8	1.6 ± 1.4	1.8 ± 2.3	0.7	3.0 ± 2.0	1.4 ± 1.5	2.5 ± 3.4
Rope/strapping	n items (nests)	42 (29)	125 (43)	–	1 (1)	–	–	–	4
	Length (cm)	32.2 ± 36.6	31.3 ± 35.5	–	23.0	–	–	–	15.2 ± 7.0
	Width (cm)	2.1 ± 3.3	0.8 ± 0.9	–	2.0	–	–	–	5.1 ± 4.1
	Weight (g)	1.6 ± 2.6	2.4 ± 3.8	–	2.8	–	–	–	3.5 ± 3.4
Other	n items (nests)	29 (20)	4 (4)	1 (1)	32 (20)	2 (1)	–	3 (3)	10
	Length (cm)	15.2 ± 13.0	6.1 ± 3.7	12.0	14.8 ± 12.0	5.5 ± 0.7	–	8.5 ± 10.4	10.2 ± 5.3
	Width (cm)	3.4 ± 2.7	4.0 ± 3.6	3.5	3.9 ± 3.2	4.8 ± 1.8	–	2.0 ± 1.3	5.0 ± 3.8
	Weight (g)	1.5 ± 1.7	3.9 ± 6.1	3.7	2.0 ± 2.1	1.8	–	0.8 ± 0.5	1.7 ± 1.4

[a] 87 debris items collected away from nests in the colony.

(37% vs 1%; $\chi^2 = 157.2$, d.f. = 1, $p < 0.001$) than vegetated nests. Flexible plastic packaging tended to be more frequent in vegetated than open nests, but this was not significant (27% vs 22%; $\chi^2 = 1.60$, d.f. = 1, $p = 0.206$). Nests in open areas more frequently contained debris items (54%) than nests in vegetated areas (31%; $\chi^2 = 27.893$, d.f. = 1, $p < 0.001$). Within colonies where there was a representative sample of nests in both open and vegetated areas, Strandfontein had a higher occurrence of debris items in open (82%) than vegetated nests (40%; $\chi^2 = 20.142$, d.f. = 1, $p < 0.001$). A similar trend was shown for De Mond with 78% occurrence in open nests vs 53% occurrence in vegetated nests, but this was not significant ($\chi^2 = 3.644$, d.f. = 1, $p = 0.056$). However, at Keurbooms Estuary nests in vegetated areas (44%) had a higher occurrence of debris items than nests in open areas (11%; $\chi^2 = 16.74$, d.f. = 1, $p < 0.001$).

Although included in models with substantial support (Supplemental Table 3), location type (coastal dune/inland) showed no significant effect on the frequency of occurrence of any of the five debris types (Supplemental Table 4). However, individual effects of location type on all five debris types show that coastal dune colonies have a significantly higher frequency of occurrence than inland colonies: fishing line (coastal 7% vs inland 0%; $\chi^2 = 12.31$, d.f. = 1, $p < 0.001$); material (11% vs 1%; $\chi^2 = 18.52$, d.f. = 1, $p < 0.001$); other (10% vs 2%; $\chi^2 = 11.10$, d.f. = 1, $p < 0.001$); plastic packaging (32% vs 12%; $\chi^2 = 27.41$, d.f. = 1, $p < 0.001$); and rope/strapping (17% vs 0%; $\chi^2 = 34.05$, d.f. = 1, $p < 0.001$).

Nests at De Mond (where birds were primarily incubating eggs) mainly contained rope/strapping, while the other three coastal dune colonies (all provisioning chicks) had a considerable amount of flexible plastic packaging (Fig. 1). There was a significant difference in the frequency of occurrence in both plastic packaging and rope/strapping between incubating and chick provisioning coastal dune colonies: plastic packaging (incubating 3% vs chick provisioning 37%; $\chi^2 = 28.74$, d.f. = 1, $p < 0.001$) and rope/strapping (64% vs 8%; $\chi^2 = 125.32$, d.f. = 1, $p < 0.001$). There was no significant difference in fishing line, material and other debris types between incubating and provisioning colonies: fishing line (3% vs 8%; $\chi^2 = 1.32$, d.f. = 1, $p = 0.250$); material (4% vs 12%; $\chi^2 = 2.63$, d.f. = 1, $p = 0.105$); and other (6% vs 11%; $\chi^2 = 1.06$, d.f. = 1, $p = 0.303$).

A number of models investigating the number of anthropogenic debris items found in kelp gull nests received substantial support ($\Delta AIC < 4$), and involved all three explanatory variables (Supplemental Table 5). Interestingly, model averaging showed that only location type had a significant effect on the number of debris items in nests (Supplemental Table 6). Overall, nests in coastal dune colonies contained more debris items (average: 1.77, maximum: 26) than inland colonies (average: 0.23, maximum: 5; t = 10.004, d.f. = 534.43, $p < 0.001$).

Table 3
Comparison of the occurrence of debris items (%) found in regurgitated pellets and nests of kelp gulls at two locations in the Western Cape.

	Regurgitated pellets		Nests	
	Keurbooms (n = 92)	Robberg Island (n = 40)	Keurbooms (n = 211)	Robberg Island (n = 40)
Fishing line	1.1	0.0	0.5	0.0
Material	17.4	5.0	5.7	2.5
Plastic packaging	63.0	45.0	34.6	30.0
Rope/strapping	0.0	0.0	0.5	0.0
Other[a]	78.2	95.0	9.5	2.5

[a] Other was predominantly paper in regurgitated pellets, with glass and anthropogenic food items also being common.

4. Discussion

Anthropogenic debris has spread to many areas of the natural environment, often collecting in marine locations. It is therefore no surprise that nests of the urban-adapted kelp gull contained anthropogenic debris at all seven breeding sites surveyed in the Western Cape. The proportion of kelp gull nests containing anthropogenic debris varied

among colonies (4–67%), a range similar to that reported by studies of other coastal bird species: 4–74% of brown booby (Lavers et al., 2013; Tavares et al., 2016; Verlis et al., 2014), 2–98% of northern gannet *Morus bassanus* (Bond et al., 2012; Montevecchi, 1991; Votier et al., 2011), 23–35% of Australasian gannet *M. serrator* (Norman et al., 1995), 39–57% of kittiwake (Clemens and Hartwig, 1993; Hartwig et al., 2007), 37% of double-crested cormorant *Phalacrocorax auritus* (Podolsky and Kress, 1989), 33–71% of black-faced spoonbill (Lee et al., 2015), and 3% of sooty tern *Onychoprion fuscatus* (Petersen et al., 2016) nests.

Our findings support the hypothesis that anthropogenic debris in kelp gull nests comes from two sources: nest construction and regurgitations of debris accidentally ingested. Kelp gulls collect construction materials from the area surrounding their nest site (Crawford and Hockey, 2005) and so the frequency of construction-derived debris is dependent on colony location. Nests in coastal colonies had a higher occurrence of debris items than inland colonies, because birds at coastal colonies have more access to stranded debris (pers. obs; Tavares et al., 2016; Verlis et al., 2014); there was little litter in the immediate vicinity of colonies at coastal salt pans, and none at the Steenbras Dam site. Within coastal colonies, open nests contained more fishing line, rope and material than vegetated nests, suggesting that these materials were specifically used for nest construction. This conclusion is supported by the results at De Mond, where most birds were still incubating eggs and the main debris type was rope; nests at the river mouth, where stranded vegetation was abundant, contained less debris than nests on nearby dunes with little stranded vegetation nearby (Table 1).

However, all colonies contain some debris items due to debris derived from their diet. This explains the preponderance of food-related bags and wrappers at inland locations. Examination of adult regurgitations of indigestible prey remains confirm that flexible packaging and other debris items are commonly ingested by kelp gulls (Table 3). These items can become trapped in the nest bowl, and are more likely to be retained in vegetated areas, where the nest structure tends to be larger and more sheltered, as was seen at the Keurbooms Estuary. However, this greater retention may be offset in more open coastal sites by gulls using debris for construction purposes (hence the greater abundance of all debris in open nests at Strandfontein and De Mond). Dietary-derived debris, in particular, is affected by the distance to nearest urban waste landfill, with the abundance of flexible packaging decreasing with increasing distance from urban waste landfill sites. The abundance of dietary-debris is also affected by breeding stage as once eggs hatch parents begin bringing food to the nest, and debris items are added to the nest when food containing these items is regurgitated to feed the chicks.

Overall, most debris found in kelp gull nests was flexible plastic packaging (predominantly from diet) or rope/strapping (mainly from nest construction), with fishing line (also used for nest construction) being the least frequent. Fishing gear is a frequent constituent of anthropogenic debris used for nesting material by seabirds that collect nesting material at sea (Bond et al., 2012; Montevecchi, 1991; Verlis et al., 2014). The low incidence of fishing line in our study can be attributed to the fact that kelp gulls typically collect nesting material in the breeding colony. Most if not all of the rope/strapping and fishing line found in gull nests probably was collected from the shoreline. The large amount of flexible plastic packaging found in kelp gull nests can be attributed to their scavenging nature. We thus found support for all our hypotheses: 1) debris is mainly used for nest construction at coastal colonies due to the abundance of stranded beach litter; 2) at coastal sites, construction debris is more abundant at open sites where other nesting material is scarce; 3) plastic and other debris from gull regurgitations accumulate in and around nests throughout the breeding season; and 4) dietary-debris is more abundant at colonies close to urban landfill sites.

The frequent occurrence of anthropogenic debris items in kelp gull nests is of concern; we observed chicks and adults entangled in fishing line at Strandfontein and Keurbooms Estuary, as well as flexible plastic packaging at Keurbooms Estuary (Supplemental Figs. 2, 3 and 4). It is important for the sources of debris items to be identified, so that appropriate management of these areas can be implemented to reduce the amount of debris items available to gulls. It is likely that many anthropogenic debris items are collected from urban waste landfills, which require improved management to reduce scavenging by kelp gulls and other species. It has been suggested that during periods of high visitation, exposed areas could be covered with soil or a commercial cover material (Belant, 1997). The ideal would be to separate waste types so that persistent wastes are separated from organic wastes that attract gulls to urban waste landfills before disposal.

Acknowledgements

We thank the relevant landowners for access to gull colonies. Financial support was received from the National Research Foundation, the University of Cape Town, the University of KwaZulu-Natal, BirdLife South Africa and BirdLife Plettenberg Bay. The Nature's Valley Trust is thanked for support throughout this research. Shirley Van de Voorde is thanked for assistance in the field.

Appendix A. Supplementary data

Supplementary data to this article can be found online at doi:10.1016/j.marpolbul.2016.10.052.

References

Barnes, D.K.A., Galgani, F., Thompson, R.C., Barlaz, M., 2009. Accumulation and fragmentation of plastic debris in global environments. Philos. Trans. R. Soc. B 364, 1985–1998.
Belant, J.L., 1997. Gulls in urban environments: landscape-level management to reduce conflict. Landsc. Urban Plan. 38, 245–258.
Bergmann, M., Gutow, L., Klages, M. (Eds.), 2015. Marine Anthropogenic Litter. Springer International Publishing, Heidelberg.
Bond, A.L., Montevecchi, W.A., Guse, N., Regular, P.M., Garthe, S., Rail, J.-F., 2012. Prevalence and composition of fishing gear debris in the nests of northern gannets (*Morus bassanus*) are related to fishing effort. Mar. Pollut. Bull. 64, 907–911.
Burnham, K.P., Anderson, D.R., 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach. Springer-Verlag, New York.
Clemens, T., Hartwig, E., 1993. Müll als nistmaterial von dreizehenmöwen (*Rissa tridactyla*) - untersuchung einer brutkolonie an der Jammerbucht, Dänemark. Seevögel 14, 6–7.
Crawford, R.J.M., Hockey, P.A.R., 2005. Kelp gull. In: Hockey, P.A.R., Dean, W.R.J., Ryan, P.G. (Eds.), Roberts Birds of Southern Africa, 7 ed. The Trustees of the John Voelcker Bird Book Fund, Cape Town, pp. 439–441.
Derraik, J.G.B., 2002. The pollution of the marine environment by plastic debris: a review. Mar. Pollut. Bull. 44, 842–852.
Duhem, C., Roche, P., Vidal, E., Tatoni, T., 2008. Effects of anthropogenic food resources on yellow-legged gull colony size on Mediterranean islands. Popul. Ecol. 50, 91–100.
Gregory, M.R., 2009. Environmental implications of plastic debris in marine settings – entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. Philos. Trans. R. Soc. B 364, 2013–2025.
Hartwig, E., Clemens, T., Heckroth, M., 2007. Plastic debris as nesting material in a kittiwake (*Rissa tridactyla*) colony at the Jammerbugt, northwest Denmark. Mar. Pollut. Bull. 54, 595–597.
Kühn, S., Bravo Rebolledo, E.L., van Franeker, J.A., 2015. Deleterious effects of litter on marine life. In: Bergmann, M., Gutow, L., Klages, M. (Eds.), Marine Anthropogenic Litter. Springer International Publishing, Cham, Switzerland, pp. 75–116.
Laist, D.W., 1987. Overview of the biological effects of lost and discarded plastic debris in the marine environment. Mar. Pollut. Bull. 18, 319–326.
Laist, D.W., 1997. Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In: Coe, J.M., Rogers, D.B. (Eds.), Marine Debris. Springer-Verlag, New York, pp. 99–139.
Lavers, J.L., Hodgson, J.C., Clarke, R.H., 2013. Prevalence and composition of marine debris in brown booby (*Sula leucogaster*) nests at Ashmore Reef. Mar. Pollut. Bull. 77, 320–324.
Lee, K., Jang, Y.C., Hong, S., Lee, J., Kwon, I.K., 2015. Plastic marine debris used as nesting materials of the endangered species black-faced spoonbill *Platalea minor* decreases by conservation activities. J. Korean Soc. Mar. Environ. Energy 18, 45–49.
Lisnizer, N., Garcia-Borboroglu, P., Yorio, P., 2011. Spatial and temporal variation in population trends of kelp gulls in northern Patagonia, Argentina. Emu 111, 259–267.
Montevecchi, W., 1991. Incidence and types of plastic in gannets' nests in the northwest Atlantic. Can. J. Zool. 69, 295–297.
Nel, D., Nel, J., 1999. Marine debris and fishing gear associated with seabirds at sub-Antarctic Marion Island, 1996/97 and 1997/98: in relation to longline fishing activity. CCAMLR Sci. 6, 85–96.

Norman, F., Menkhorst, P., Hurley, V., 1995. Plastics in nests of Australasian gannets *Morus serrator* in Victoria, Australia. Emu 95, 129–133.
Ostrowski, S., Shobrak, M., Al-Boug, A., Khoja, A., Bedin, E., 2005. The breeding avifauna of the Umm al-Qamari Islands protected area, Saudi Arabia. Sandgrouse 27, 53–62.
Petersen, E.S., Krüger, L., Dezevieski, A., Petry, M., Montone, R.C., 2016. Incidence of plastic debris in sooty tern nests: a preliminary study on Trindade Island, a remote area of Brazil. Mar. Pollut. Bull. 105, 373–376.
Podolsky, R.H., Kress, S.W., 1989. Plastic debris incorporated into double-crested cormorant nests in the Gulf of Maine. J. Field Ornithol. 60, 248–250.
Provencher, J.F., Bond, A.L., Mallory, M.L., 2014. Marine birds and plastic debris in Canada: a national synthesis and a way forward. Environ. Rev. 23, 1–13.
Ryan, P.G., 1987. The incidence and characteristics of plastic particles ingested by seabirds. Mar. Environ. Res. 23, 175–206.
Ryan, P.G., Moore, C.J., van Franeker, J.A., Moloney, C.L., 2009. Monitoring the abundance of plastic debris in the marine environment. Philos. Trans. R. Soc. B 364, 1999–2012.
Tavares, D.C., da Costa, L.L., Rangel, D.F., de Moura, J.F., Zalmon, I.R., Siciliano, S., 2016. Nests of the brown booby (*Sula leucogaster*) as a potential indicator of tropical ocean pollution by marine debris. Ecol. Indic. 70, 10–14.
Verlis, K., Campbell, M., Wilson, S., 2014. Marine debris is selected as nesting material by the brown booby (*Sula leucogaster*) within the Swain Reefs, Great Barrier Reef, Australia. Mar. Pollut. Bull. 87, 180–190.
Votier, S.C., Archibald, K., Morgan, G., Morgan, L., 2011. The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality. Mar. Pollut. Bull. 62, 168–172.
Yorio, P., Borboroglu, P.G., 2002. Breeding biology of kelp gulls (*Larus dominicanus*) at Golfo San Jorge, Patagonia, Argentina. Emu 102, 257–263.