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Plastic ingestion by a generalist seabird on the coast of Uruguay

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ABSTRACT

We analyzed plastic ingestion by Kelp Gull (*Larus dominicanus*) from 806 pellets collected between 2011 and 2013. Employing a Raman spectroscopy, we characterized those polymers used to produce the plastics ingested. Debris was recorded in 143 pellets (%FO = 17.7%, n = 202, 92.58 g). Plastic was found in 119 pellets (%FO = 83%) and non-plastic occurred in 56 pellets (%FO = 39%). The most important debris category was plastic film with 55.3% (n = 79). Plastic bags were observed in 19 pellets (%FO = 2.4%, weight = 25.02 g). Glass was the second most important component (%FO = 18.9%) followed by plastic fragments (%FO = 17.8%). Plastic debris represented the 65.3% of the debris fragments (n = 132, weight = 58.84 g), and was composed by polyethylene (52%), polypropylene (26%), polyamide (12%), polystyrene (6%), polyvinyl chloride (2%), and polyethylene terephthalate (2%). How plastics were obtained by gulls and the effects on individuals are discussed, as well as environmental considerations about plastic pollution on coastal environments.

1. Introduction

Semi-synthetic products, resulting from a combination of natural tissues and chemicals, started to appear in our daily life in 19th century as a cheap substitute for increasingly scarce natural materials like ivory, wood, or hard-working manufacturing products such as glass or metal (Moore and Phillips, 2011). But it was not until after the second world-war that synthetic plastics became to be used massively changing humanity lifestyle, for instance in transport, packaging, clothing, food, health care, construction, and telecommunications (Thompson et al., 2009). Since then, plastics rapidly increased their presence in our modern debris (Barnes et al., 2009). Due to their massive use and persistence, plastics have been accumulating in aquatic ecosystems such as beaches, waterways, estuaries, lakes, the open as well as the deep sea (Free et al., 2014; Lima et al., 2014; Moore et al., 2011; Moore and Phillips, 2011; Van Cauwenberghe et al., 2013). For instance, Moore et al. (2011) showed that only two rivers in California drained to the Pacific Ocean 30 metric tons of plastic debris every 72 h. The global ubiquity of this material entails the need to fully understand the magnitude of plastic pollution and create measures to mitigate it.

Ecological consequences of plastic-biodiversity interactions are one of the most important environmental problems globally. For instance, marine organisms that are entangled with plastic objects (e.g., packaging bands, ropes, fishing lines, or drift nets) suffer from drowning, strangulation, reduction of foraging efficiency and reproduction (Derraik, 2002; Moore, 2008). Consequently, effects are generally related with death, or a reduction in fitness. In Uruguay plastic pollution in aquatic ecosystems has been recently reviewed and has been detected that fresh water fishes, marine turtles, and seabirds ingest plastic objects, and that rafting plastic pieces can transport and improve dispersal of invasive marine invertebrates (Lozoya et al., 2015).

Plastic ingestion by seabirds has received increasing attention globally over the last years (e.g., Acampora et al., 2014; Avery-Gomm et al., 2013; Blight and Burger, 1997; Codina-García et al., 2013; Jiménez et al., 2015; Lavers et al., 2013; Ryan and Fraser, 1988; van Franeker and Law, 2015). Evidence has rapidly increased on pelagic seabirds such as Shearwaters, Albatrosses, and Petrels that are not able to produce pellets and often die because of obstruction of their digestive tract. However, a less amount of studies have explicitly assessed plastic pollution on coastal seabirds like gulls (Lindborg et al., 2012; Yorio et al., 2014), but see Camphuysen et al. (2008); Ceccarelli (2009); Thiel et al. (2011), and Kühn et al. (2015) for further information. This species is generally easier to study because a great amount of data can be obtained in a short period of time by pellet analysis.

Moreover, Kelp Gull (*Larus dominicanus*) is a suitable species to assess plastic ingestion because it is widely distributed throughout its range. This species breeds in the Southern Hemisphere: South America, South Africa, New Zealand, Subantarctic Islands and in the Antarctic Peninsula (Harrison, 1983), and in Uruguay reproduce on eight

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coastal islands and group of islands (Yorio et al., 2016). This species is perceived by scientists and managers as an environmental concern. For instance, a) it is a potential vector of pathogens (e.g. *Enterobacteriaceae*), b) predate eggs and chicks of sympatric breeding species, affecting in some cases, the reproductive performance of threatened populations, c) feeds on skin and fat of Southern Right Whales (*Eubalaena australis*) modifying the behavior of mothers and calves during their breeding season, and d) they are a threat to airport security as they are a risk for aircraft collisions (Frere et al., 2000; Lenzi et al., 2010; Rowntree et al., 2001; Yorio et al., 2016; Yorio and Quintana, 1997). On the other hand, Kelp Gulls have been reported to be killed and injured by marine debris such as fishing lines in Argentina (Yorio et al., 2014).

In addition, Kelp Gull is a generalist seabird that learned how to exploit energy subsidies such as garbage (Yorio and Giaccardi, 2002) and fishing discards (González-Zevallos and Yorio, 2006) that are easily acquired. As with other *Larus* sp., several researchers proposed that these food supplies could have a significant effect in the increase of their populations along its distributional range (Coulson and Coulson, 1998; Giaccardi et al., 1997; Yorio et al., 1998). Therefore, this trait of its natural history could potentially intensify the negative effects described above.

In Uruguay, there has been detected that Kelp Gull feeds on a great variety of natural prey, including debris. One of the most important anthropogenic food items identified in its diet were plastic objects (Lozoya et al., 2015). As Kelp Gulls frequently forage in landfills (Bertellotti et al., 2001; Giaccardi et al., 1997; Yorio and Giaccardi, 2002), they can find a large amount of organic food but also synthetic products that they can ingest. This figure may be occurring in Uruguay because Kelp Gull breeding colonies are close to urban areas, and subsequently to garbage dumps.

In this paper we made an assessment of plastic ingestion by Kelp Gull in a breeding colony of Uruguay from pellets collected between 2011 and 2013. In addition, using Raman spectroscopy we characterized the polymers employed to produce the plastic objects ingested, and further track the potential commercial products where they come from.

2. Materials and methods

2.1. Study area

Isla de las Gaviotas (34°54′10″ S, 56°06′16″ W) is located 400 m off Montevideo city and is a small island with a surface of 1.7 ha. Guido et al. (2013) analyzed the vegetation of the island and found that it is dominated by herbaceous plants and some woody species such as Canary Palm (*Phoenix canariensis*), Castor Oil Plant (*Ricinus communis*) and Saltcedar (*Tamarix ramosissima*). Despite its small size this island is habitat of more than 40 bird species (Unpubl. data) some of them of national conservation concern (Soutullo et al., 2009). Breeding population size of the Kelp Gull is small, which was estimated in 115 breeding pairs (Yorio et al., 2016), however, non-breeding population size is about five times higher. Kelp Gull breeds on the island in sympatry with American Oystercatcher (*Haematopus palliatus*), Cattle Egret (*Bubulcus ibis*), and Snowy Egret (*Egretta thula*).

2.2. Pellet analysis

Pellet samples were collected on Isla de las Gaviotas during 31 surveys between 2011 and 2013 (Fig. 1). Pellets are those structures regurgitated by several bird species containing hard parts that are not digestible (Barrett et al., 2007). This technique has the advantage of being non-invasive, simple, and can provide large amount of information in a short period of time (Karnovsky et al., 2012). As pellets were collected in the same sites of the island, we can assume that pellets integrate the diet of the population between surveys. A total of 806 pellets were collected and analyzed in the laboratory where particles of debris were separated, weighted (to the nearest 0.001 g.), and stored for

Fig. 1. Location of Isla de las Gaviotas on the coast of Montevideo city.

further analysis, considering the pellet from which they came. Debris was categorized as plastic and non-plastic materials. Then, we subdivided both categories as follows. Plastic: plastic film, user plastic, threadlike user plastics, laminated paper, styrofoam, and rubber; non-plastic: glass, threads, paper, metal, ceramic, and cotton. Although resin pellets were not present in the diet of the Kelp Gull (see Results), the category user plastic was created in order to differentiate both sources of plastic and facilitate comparison with other studies (see van Franeker and Law, 2015).

2.3. Plastic analysis

A sub-set of samples were selected randomly for polymer identification considering that we were able to analyze a limited amount of 50 samples. In order to determine sub-sample size per category, we took the sub-samples considering the size of the categories into account: plastic film (24 of 82: 30%), user plastics (15 of 26: 57%), threadlike user plastics (9 of 16: 56%), and foam (2 of 3: 66%). A less proportion of sub-samples was analyzed for plastic film as we expected to have less diversity in the polymer composition, and we wanted to explore more deeply the nature of User plastic materials.

In order to characterize polymer composition, the subsample was analyzed using Raman spectroscopy with a Raman imaging microscope (Thermo Scientific™ DXR™xi). Cross-sectioned samples for Raman analysis were prepared using the Thermo Scientific™ Polymer Slicing Tool for DXR Raman microscopes.

2.4. Data analysis

Data analysis was carried out considering that our primary interest was to analyze the composition of the debris found in the diet of the Kelp Gull. Therefore, we estimated those indices commonly used in the literature (see Silva-Costa and Bugoni, 2013) considering the total amount of debris as our population: number of pellets (i.e. number of pellets where each category was present), frequency of occurrence (%FO as percentage of each category relative to the amount of pellets that contained debris), numeric percentage (%N as percentage of the number of debris fragments of each category relative to the total number of fragments), weight (sum of the weights of each category), and percentage of weight (percentage relative to the total debris weight).

3. Results

3.1. Debris composition

From the 806 analyzed pellets, 143 had debris (%FO = 17.7%), represented by 202 debris fragments and 92.58 g (Fig. 2). Debris weight did not show variation among years (ANOVA: $F_{1,203} = 0.008$, $P > 0.05$). Within the array of pellets containing debris, plastic was found in 119 pellets (%FO = 83%) while non-plastic debris occurred in 56 pellets (%FO = 39%; we have to consider that in one pellet we will find plastic and non-plastic debris, so the sum of these percentages will be more than 100). Weight of plastic debris was 61.33 g. (66%) and weight of non-plastic debris summed 31.25 g. (34%).

The most important debris category was plastic film, found in 79 pellets that corresponded to 55.2% of pellets containing debris (Table 1, Fig. 2a). Also its weight was the most important in terms of total weight (28.82 g.), percentage (31.1% of all the debris) and %N (40.6%) (Table 1). When a plastic film occurred in a pellet, sometimes it occupied 100% of it, because it frequently corresponded to an entire plastic bag or a big piece of it (Fig. 3a). We detected plastic bags in 19 pellets (24% of those pellets containing plastic films), which corresponded to 13.0% of all the pellets containing debris. Their average weight was 1.32 g. per pellet and the total weight was 25.02 g. Surprisingly, glass was the second most important component of the debris (Table 1, Fig. 2). Plastic fragments were the third most important category followed by threads and plastic paper (Table 1, Fig. 3). Paper, metal and styrofoam were among the less important categories, while ceramic, cotton, and rubber, were of less importance (Table 1, Fig. 3).

3.2. Polymer composition

Of the 202 debris fragments that were found in pellets, 132 (65%) were plastic debris, which weighted 58.84 g (65.3% of total debris). The sub-set of 50 sub-samples analyzed to determine polymer composition showed that polyethylene (PE) was the most important polymer found in the diet of *Larus dominicanus* with 52% (n = 26). Then, polypropylene (PP) was the second most important with 26% (n = 13). Polyamide (PA) was also high with 12% (n = 6). Other polymers were found in lower frequency: polystyrene (PS, 6%, n = 3), polyvinyl chloride (PVC, 2%, n = 1), and polyethylene terephthalate (PET, 2%, n = 1).

If we consider polymer composition within each sub-sample, plastic film was composed by 22 fragments of PE (92%), 1 of PP (4%), and 1 of PET (4%). User plastics were mostly composed by PP (80%) followed by PE, PS, and PVC with one fragment (7%) each. Threadlike user plastics were mainly PA with six fragments (67%) and PE with three fragments (33%). Finally, the two fragments of styrofoam were composed entirely by PS.

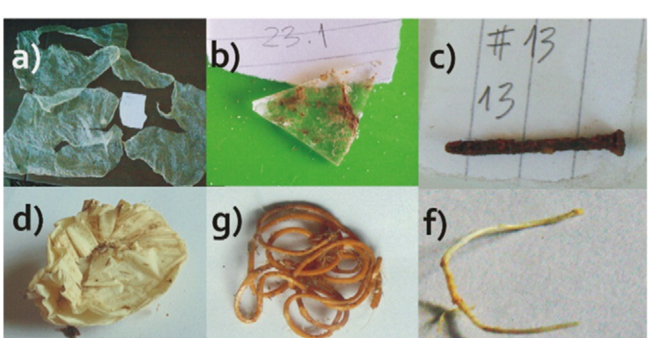

Fig. 2. Some samples of debris categories found in the diet of the Kelp Gull on Isla de las Gaviotas. a) Plastic film, b) glass, c) metal, d) paper, e) rubber, and f) thread.

Table 1
Types of debris found in Kelp Gull pellets on Isla de las Gaviotas. *Synthetic polymers that were later analyzed by using Raman spectroscopy.

Debris category	No. pellets	FO	%N	Weight	%weight
Plastic film*	79	55.2	40.6	28.82	31.1
Threadlike user plastics*	16	11.2	7.9	0.33	0.4
Glass	34	23.8	21.3	16.15	17.4
Rubber	1	0.7	0.5	0.02	0.0
Threads	13	9.1	6.4	2.22	2.4
User plastic*	24	16.8	12.9	26.8	29.0
Paper	5	3.5	2.5	5.19	5.6
Foam	3	2.1	1.5	0.31	0.3
Metal	5	3.5	2.5	2.69	2.9
Laminated paper	6	4.2	3.0	4.97	5.4
Ceramic	1	0.7	0.5	3.96	4.3
Cotton	1	0.7	0.5	1.05	1.1

4. Discussion

Plastic film was the most important debris category, while polyethylene and polypropylene were the most important polymers found in pellets. Based on that, we can suggest that bags and plastic films may be a primary plastic contaminant for the Kelp Gull. These particular products are commonly known by poly bags and are widely used for instance in the food industry and as liners for an extensive array of products. As there are no restrictions for its use in Uruguay or in the region, this product is widely used and widespread in open dumps and in the inner zone of the Rio de la Plata estuary, as well (Acha et al., 2003; Lozoya et al., 2015).

The nature of the debris found in the pellet samples suggests that a high proportion, if not all of it, comes from landfills. For instance, we found threads used in food manufacturing, medication wrappers, clothing labels, parts of food wrappers and containers. Furthermore, organic matter was found in the samples (e.g., chicken bones, terrestrial invertebrates, small rodents, Unpubl. data) supporting the idea that gulls use landfills to forage at a great extent. Moreover, in studies where stomach contents are analyzed, such as in pelagic seabirds, plastic pellets are frequently recorded suggesting that they do not come from landfills, but from oceanic or coastal environments. Future investigations should quantify how much plastic and garbage come from

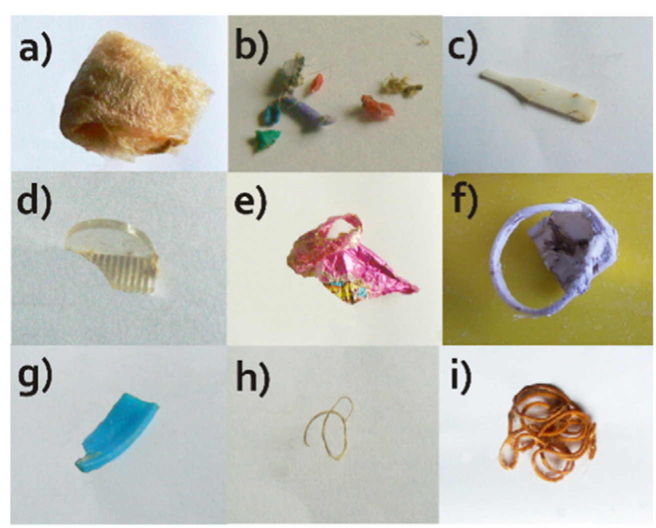

Fig. 3. Fragments of synthetic polymers found in the diet of the Kelp Gull on Isla de las Gaviotas. a) Plastic bag, b) plastic fragments, c) tip of a disposable coffee spoon, d) fragment of a compact disk case, e) candy envelope, f) container security cover, g) plastic fragment, h) plastic thread, and i) rubber band.

landfills, shoreline or the ocean to delineate management strategies for coastal species.

In addition, those species or individuals that use landfills to forage may be considered dispersal sources of plastics from inland to coastal regions and the oceans. This pathway of plastic transportation may be added to the list of already known ways, such as waterways carrying debris of human activities (landfills included), recreational activities on the coast, marine traffic, failure in cleaning systems of municipalities, among others (Derraik, 2002; Lozoya et al., 2015). In addition, an assessment of this potential new connection between landfills and the ocean should be conducted in the future. Particularly, a quantification of the amount of debris carried by gulls from the inland to the coast would be necessary.

Identification of polymers may be a powerful tool to suggest what kind of products may be observed in seabirds' diets. For example, polyethylene was the most important polymer found in this study and is used to produce plastic bags and plastic films. These particular products are commonly known as poly bags and are widely used, for instance in the food industry and as liners for an extensive array of products. As there are no restrictions for its use in Uruguay or in the region, this product is commonly found in open dumps and in the inner zone of the Rio de la Plata estuary, as well (Acha et al., 2003; Lozoya et al., 2015).

Surprisingly, glass was the second most important debris component in the diet of the Kelp Gull. Other studies such as Coulson and Coulson (1993) also found glass with a lot of refuse in the Kelp and Pacific (*Larus pacificus*) gulls in southern Tasmania. In Argentina glass was recorded in the diet of the Kelp Gull, although its occurrence was very low and not quantified (Bertellotti and Yorio, 1999) or classified as garbage (Petracci et al., 2004). In addition, glass was also recorded in other species of gulls like Herring Gull (*Larus argentatus*) and Lesser Black-backed Gull (*Larus fuscus*), Yellow-legged Gull (*Larus michahellis*), Pacific Gull (*Larus pacificus*), Great Black-backed Gulls (*Larus marinus*), and Glaucous-winged Gull (*Larus glaucescens*) (Camphuysen et al., 2008; Coulson and Coulson, 2008; Ewins et al., 1994; Gilliland et al., 2004; Lindsay and Meathrel, 2008; Neves et al., 2006; Nogales et al., 1995; Trapp, 1979). On the other hand, glass was not recorded in the diet of a Kelp Gull population in Peru as it nested on an island far from anthropogenic food sources (Flores, 2005).

To explain the important amount of glass as debris component, three possible non-mutually exclusive explanations could be drawn. First, glass is made from attractive and bright colors that may be interesting for the Kelp Gull to feed on. However, to our knowledge there is no antecedent about the incidence of coloration in food selection in gulls. Additionally, feeding on glass could also play the same role as feeding on stones in the digestive process (Nogales et al., 1995) by helping in crushing those hard items in the gizzard (Goutner, 1994). Finally, its ingestion could also be accidental while trying to feed on other items. We can add to this figure the fact that glass availability may be very important in landfills because recycling has completely stopped since 90's, despite that since 2008 glass started to be recycled again but in a very limited amount.

Digestive tract of Kelp Gulls may allow them to regurgitate plastic fragments without dying of starvation as occurs in Procellariform species. Charadriiformes, like gulls, do not have the constriction between the gizzard and proventriculus as Procellariforms do, so gulls are able to regurgitate plastic fragments in pellets along with other indigestible materials (Azzarello and Van Vleet, 1987; Bergmann et al., 2015; Furness, 1985b; Lindborg et al., 2012). Although Gull's direct mortality resulting from plastic ingestion may not be common, it has not been thoroughly evaluated yet, as well as those indirect and sub-lethal effects. Nevertheless, gull mortality has been recorded by entangling with monofilament (polyamide) lines and fishing nets (Berón and Favero, 2009; Gregory, 2009; Moore et al., 2009; Taylor, 1996; Yorio et al., 2014). Yorio et al. (2014) found that, during a survey carried out in four Kelp Gull breeding colonies along nine days, 27 individuals were tangled and 22 of them were freshly dead. This indicates that lethal effects of plastics on gulls can be related with entanglement more than by direct ingestion.

Even though gulls may not die by plastic ingestion, they face several challenges that could affect their fitness. Seabirds can suffer a reduction in hunger and satiety, or a reduction in the stomach volume preventing them to assimilate food correctly (Ryan, 1989). Moreover, plastic "compete" with food in the gizzard reducing the amount of preys that could be digested. This situation may lead to a decrease in foraging efficiency as individuals have to allocate more time and energy to forage (Ryan, 1989). This situation may limit the amount of energy that could be allocated to life history traits like body weight, reproduction, development, or survival (Ryan, 1989; Stearns, 1992). Although our knowledge of these effects in seabirds' life histories is limited, evidence that body weight and condition are negatively affected by plastic ingestion is available for other seabird species, including pellet producers like Charadriiformes (Furness, 1985a; Spear et al., 1995). Knowledge from other animal taxa such as lugworms and barnacles (Besseling et al., 2012; Hentschel, 2015; Wright et al., 2013) supports the claim that plastic ingestion affects individuals' life histories and that more studies are necessary to quantify the effect size of this animal-plastic interaction.

Another important aspect of plastic debris ingestion by seabirds is the exposure to organic contaminants (e.g., persistent organic pollutants, POPs) associated with plastics. It is well known that plastic debris accumulates contaminants due to its hydrophobic nature. Persistent organic pollutants include industrial chemicals such as polychlorinated biphenyls (PCBs), and chlorinated pesticides such as dichlorodiphenyltrichloroethane (DDT), hexachlorobenzene (HCB) or hexachlorocyclohexanes (HCHs). Several reports (Ogata et al., 2009; Rios et al., 2007) have found the occurrence of POPs on marine plastic debris and that plastics are important sources of these contaminants into the marine environment. Moreover, several studies have found POPs in the tissues of seabirds with a similar contamination profile than the plastic debris associated with the animals analyzed (Colabuono et al., 2010). Thus, there is a concern regarding the possible transfer and deleterious effects of these contaminants from plastics to the marine organisms.

Unmanaged open sky landfills may be the main source for plastics ingested by gulls, as well as for plastic pollution on the coast and oceans. When landfills are managed food availability is reduced, because landfills are less attractive to them (Giaccardi et al., 1997). These authors found that abundance of Kelp Gull decreased in a landfill in Argentina after management practices were implemented. In addition, Lozoya et al. (2015) found that waterways can be an important way of plastic transportation from landfills to the coast of Uruguay. These authors estimated that 15 landfills were less than 300 m from the nearest waterway, and two of them were placed directly on waterways or discharging their leakages directly into a waterway. Accordingly, proper management of landfills needs to be a priority to reduce plastic ingestion by gulls as well as pollution on the coast.

The high proportion of plastic debris in the diet of the Kelp Gull on Isla de las Gaviotas reinforces the general idea that production and use of plastics need to be regulated, as it is known how harmful they are for the environment (e.g., Gregory, 2009; Moore, 2008). Fortunately, there are countries and local governments that have been increasingly taking actions to reduce their use, for instance India or Bangladesh (Ritch et al., 2009), and recently the State of California in the United States. Unfortunately, although legislation in Uruguay seems to be modern and "inspired in European Directives" (Lozoya et al., 2015), it is not enforced by the government.

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