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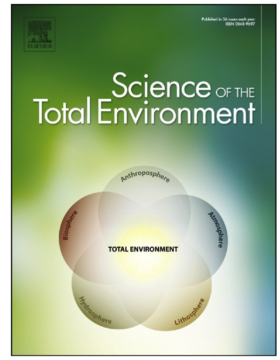

Plastic ingestion and dispersion by vultures may produce plastic islands in natural areas

Fernando Ballejo, Pablo Plaza, Karina L. Speziale, Agustina P. Lambertucci, Sergio A. Lambertucci

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TITLE:

Plastic ingestion and dispersion by vultures may produce plastic islands in natural areas

Authors: Fernando Ballejo*#, Pablo Plaza*, Karina L. Speziale, Agustina P. Lambertucci, Sergio A. Lambertucci

*Both authors contributed equally to this manuscript.

Affiliation:

Grupo de Investigaciones en Biología de la Conservación, INIBIOMA- CONICET, Universidad Nacional del Comahue, Quintral 1250 (R8400FRF), San Carlos de Bariloche, Argentina.

Corresponding author: Fernando Ballejo; E-mail: fernandoballejo@gmail.com

ABSTRACT

Rubbish dumps can become an important environmental source of plastic. Several species feed on organic waste from these sites, but at the same time are exposed to non-organic materials. Species that can gather food in these sites might at the same time disperse waste consumed, but this has rarely been evaluated. We compare the occurrence of plastic debris in regurgitated pellets of three sympatric vultures from northwest Patagonia, Andean condors (*Vultur gryphus*), black vultures (*Coragyps atratus*) and turkey vultures (*Cathartes aura*), foraging in different degrees of humanized sites. We also evaluate the influence of rubbish dumps in the presence of plastic debris in pellets of the studied species and their potential role in spreading plastic to the environment. Most synthetic material present in pellets was plastic. Pellets of Andean condors, which avoid disturbed anthropic sites in this area, showed almost no plastic debris compared with the other sympatric vulture species, suggesting an influence of the foraging habits on plastic ingestion. For black and turkey vultures, we found that dumps may be an important source of plastic. The occurrence of plastic debris in pellets of black vultures sampled in 2010 and 2020 increased, probably associated with the increase in urbanization and waste production in the study area. Avian scavengers were exposed to and are able to transport plastic to distant communal roosts generating "plastic islands". It is necessary to reduce plastic generation and better waste management practices to avoid species and environments to be affected by this pollutant.

KEYWORDS

Pellets, Plastic pollution, Rubbish dumps, Scavengers, Urbanization

1. INTRODUCTION

Humans are producing large quantities of waste that is discarded mainly in rubbish dumps (Hoornweg et al., 2013; Hoornweg and Bhada-Tata, 2012). Part of this waste is composed of organic material from household food remains (Parfitt et al., 2010). However, a large proportion of discarded waste has inorganic items such as glass, wire, paperboard, cloth fragments, and particularly plastic debris in the form of containers (e.g., drink bottles) or films (e.g., carrier bags, packaging sheets) (Barnes et al., 2009). Most plastic generated around the world is discarded (Geyer et al., 2017). For instance, from an annual global production of 280 million tons of plastic in 2012, almost half was discarded in landfills (Rochman et al., 2013). This is concerning because plastic debris remains in the environment from hundreds to thousands of years (Barnes et al., 2009), and may produce important impacts on natural habitats and subsequently on biodiversity.

One of the most important environmental sources of plastic pollution is rubbish dumps (Barnes et al., 2009; Geyer et al., 2017; Yadav et al., 2020). Plastic present in these sites can be transported and dispersed to the ecosystem through different mechanisms. For instance, plastic may be blown by wind, carried away by precipitation, floods, leaching, but it may also be dispersed by animals (Yadav et al., 2020). Diverse animal species take advantage of rubbish dumps because they provide a source of food (meat and vegetables, Parfitt et al., 2010) which is worldwide distributed, abundant, renewed daily and spatially and temporally predictable (Oro et al., 2013; Plaza and Lambertucci, 2017). However, mixed up with these organic items, there are important quantities of dangerous plastic items that can be ingested by animals (Plaza and Lambertucci, 2017; Rochman et al., 2013; Yadav et al., 2020). Therefore, while food sources present in rubbish dumps are abundant and easy to find, they hide dangerous items that can produce different impacts on species taking advantage of these sites. For instance, birds such as storks, gulls, and avian scavengers accidentally ingest plastic in dumpsites. These plastic fragments may not only produce health problems on those species but they can also be transported and dispersed to distant sites (Henry et al., 2011; Houston et al., 2007; Yorio et al., 2020). However, plastic transport by animals remains poorly studied and almost exclusively in marine species.

Vulture species are obligate scavenger birds with several species using rubbish dumps as food resources around the world (e.g., Gangoso et al., 2013; Houston et al., 2007; Plaza et al., 2018; Pomeroy, 1975). This feeding habit has produced diverse impacts on them associated with the consumption of organic waste but also synthetic material (e.g., nutritional problems, infections, metabolic alterations, lacerations, intestinal obstructions; Mee et al., 2007; Plaza et al., 2018; Plaza and Lambertucci, 2018a; Rideout et al., 2012; Tauler-Ametlller et al., 2019). Part of the plastic debris ingested when consuming organic waste is then regurgitated in their pellets (Augé, 2017; Houston et al., 2007; Iñigo Elias, 1987; Sazima, 2013). Pellets of birds of prey are not immediately regurgitated (Grimm and Whitehouse, 1963; Tarboton, 1977), and vultures can travel long distances daily (Alarcón and Lambertucci, 2018a). Therefore, they may be acting as vectors of plastic debris dispersing plastic ingested in anthropic sites towards remote, sometimes pristine areas.

Whereas northwest Patagonia is among the most pristine sites in the world, different urban settlements produce large amount of waste daily which are discarded in open rubbish dumps, with poor waste management (Plaza and Lambertucci, 2018a). This area is inhabited by three main scavenging birds: the Andean condor (*Vultur gryphus*), the black vulture (*Coragyps atratus*), and turkey vulture (*Cathartes aura*). In Patagonia, these are sympatric species and share food sources composed mainly by lagomorphs, and wild and domestic ungulates, but they also show differences in their feeding habits and tolerance to humanized sites (Ballejo et al., 2018; Barbar et al., 2015; Bellati, 2000). In this area, Andean condors avoid humanized sites for feeding, while the black and the turkey vulture tolerate these places (Bellati, 2000; Plaza and Lambertucci, 2018a; Speziale et al., 2008). Given the different foraging habits and tolerance to humanized sites of these sympatric vultures in northwest Patagonia, the ingestion of plastic debris would differ among them. This could be relevant when evaluating the influence of anthropic sites, such as rubbish dumps, on vulture plastic ingestion, and thus on their health and conservation, particularly for threatened species such as the Andean condor. Moreover, vulture species feeding in rubbish dumps might involuntarily transfer plastic pollution to the natural areas where they roost communally in northwest Patagonia by carrying the plastic ingested when feeding in anthropic sites or near urban areas.

Here we aimed at understanding the effect of rubbish dumps on plastic consumption by scavenging birds and the dispersal of plastics to natural environments mediated by bird transport. We propose that: (1) the differences in Patagonian vulture species feeding habits and tolerance to humanized sites influence the occurrence of plastic debris in their pellets given that birds that tolerate human disturbed sites would dare to eat in rubbish dumps affecting the probability of ingesting plastic debris; (2) the distance between rubbish dumps and vultures' roosting sites influences the presence of plastic debris in their pellets given that a closer distance may imply higher chances of feeding in rubbish dumps and ingesting plastic debris. Moreover, vultures adjust their roosting sites according to the localization of food sources, thus individuals roosting near humanized sites usually search for food in these sites; (3) the temporal increase in human population and waste generation affects the occurrence of plastic debris in pellets given that it represents an increase in plastic waste disposed in rubbish dumps that can be ingested by vultures; and (4) vultures movement, tolerance to disturbance and communal roosting behavior favor the dispersion of plastic debris to the environment as vulture species that feed in rubbish dumps may transport plastic debris that is later discarded in their pellets when roosting far from feeding grounds. We expect that: (1) the occurrence of plastic debris in Andean condors' pellets will be lower than in black and turkey vultures ones since these latter species usually feed in humanized areas, which are important sources of plastic; (2) the amount of plastic debris found in pellets collected at roosting sites near rubbish dumps will be larger compared to pellets collected at roosting sites far from them; (3) the occurrence of plastic remains in vultures' pellets will be higher in 2020 respect to 2010, and (4) there will be more plastic debris on the ground directly under vultures' communal roosts than in the surroundings.

2. METHODS

2.1 Study area

We conducted the study in Northwestern Argentine Patagonia (Neuquén and Río Negro provinces) (36°–41°S and 71°–68°W) (Fig.1). The area is composed of woodland and steppe vegetation (Cabrera, 1971). In the area, there are farms dedicated mainly to extensive livestock, especially sheep and cows, and although this is a rather pristine area, there are diverse human settlements that produce large amount of waste disposed at open rubbish dumps. In general, these dumpsites are poorly managed waste deposits (i.e., insufficient waste management actions) with great quantities of organic and synthetic material that attract different animal species, especially facultative and obligate scavenger birds (Frixione et al., 2012; Plaza and Lambertucci, 2018a).

2.2 Study species

The Andean condor is the largest New World vulture (weight up to almost 16 kg, wingspan 3 m), and occurs from the north of Venezuela and Colombia to the south of Argentina and Chile (Alarcón et al., 2017; del Hoyo et al., 1994). It is considered Threatened in Argentina, where populations are larger than in other areas, but showing signs of retraction (Aves Argentinas, 2017). It is negatively affected by several human disturbances (Alarcón and Lambertucci, 2018b; Speziale et al., 2008; Wiemeyer et al., 2017). In our study area, there are at least around 300 individuals (Lambertucci, 2010), which mainly feed on large carcasses of sheep, red deer (*Cervus elaphus*), and cows, but also hares (*Lepus europaeus*) (Ballejo et al., 2018; Lambertucci et al., 2009b). Condors in this area, and in most of their distribution range, tend to avoid human-disturbed sites (Speziale et al., 2008). However, in central Chile, this species takes advantage of urban sites and even uses rubbish dumps as a food source (Pavez et al., 2019). Condors are highly mobile, up to around 350 km per day, but they have well-established foraging territories, and roost communally in large cliffs with shelves generally far from humanized areas (Lambertucci et al., 2014; Lambertucci & Ruggiero 2013). The number of individuals found in roosts (dozens to hundreds) is variable and depends on the roost site they are using, the number of individuals that each site may harbor, and climatic conditions (Lambertucci et al., 2008).

The black vulture is a medium-sized scavenger bird that inhabits America from North America to Chubut province in Argentina (Ferguson-Lees and Christie, 2001). In the study area, their body mass is between 1.84 and 2.69 kg (Plaza and Lambertucci, 2018a) and it is classified as Least Concern (IUCN, 2019). Black vultures feed on carcasses of different species including sheep, cattle, red deer, and hares (Ballejo and de Santis, 2013). They also consume human subsidies such as organic waste discarded in rubbish dumps (Ballejo and de Santis, 2013; Iñigo Elias, 1987; Plaza et al., 2018). Black vultures adjust their roosting sites according to food sources and move daily between their roosting sites and their food sources (Novaes and Cintra, 2013). Individuals roosting near humanized sites usually search for food in disturbed sites such as rubbish dumps (Plaza and Lambertucci, 2018a). The home range reported for this species is around 32 km^2 (Holland et al., 2017) but some individuals may travel long distances (e.g., more than 50 km) from urban sites to pristine ones (Plaza and Lambertucci, 2018a). Black vultures roost on trees, pylons, high buildings, or low cliffs reaching hundreds of individuals but it depends of roosting site used (Ferguson-Lees and Christie, 2001).

The turkey vulture is a medium-size migratory vulture (weight 2.25 kg, wingspan 1.73 m) that has successfully occupied different environments in the American continent, ranging from Canada in the north to Tierra del Fuego in the south (Kirk and Mossman, 1998). It is classified as Least Concern (IUCN, 2019). Throughout its distribution, the species inhabits a broad variety of environments, from deserts to forests, where it can locate carrion due to its developed olfactory sense and sight (Houston, 1986; Kirk and Mossman, 1998; Platt et al., 2015). Compared with the other two species, turkey vultures have a more diverse diet, including large ungulates, but also reptiles, teleost, birds, and carnivores (Ballejo et al., 2018). While in the study area they have not been commonly observed in rubbish dumps, this species has been reported consuming organic waste in other parts of America (Augé, 2017; Ferguson-Lees and Christie, 2001; Torres-Mura et al., 2015). Their movement patterns (excluding migration) are similar to black vultures' ones but they show a larger home range (around 60 km^2) (Holland et al., 2017). Turkey vultures roost in high trees or buildings reaching hundreds of individuals in these sites (Ferguson-Lees and Christie, 2001).

2.3 Field Work

We collected fresh pellets from the ground under communal roosts of each species to analyze plastic debris and other synthetic materials. The species producing the pellets sampled were confirmed by pellets shape, composition, and because we only sampled roosts used by a single species (all pellets sampled were located under roosts used by each species). Given that the probability of finding plastic decreases with the degradation process of the pellet once they lie on the ground, we only collected fresh or dry structurally intact pellets (Provencher et al., 2019).

For Andean condors, we collected pellets in 5 communal roosting sites (Chaqueñita, Condorerita, Fragua grande, Buitrera, and Pipilcura) at the base of cliffs within natural environments of the Patagonian steppe, away from urban settlements in 2009 (Fig. 1). We collected pellets of black vultures in seven roosting sites in 2010, six of them located on trees, and one in an abandoned building (Victoria). Three of them were in the Patagonian steppe, an area used for extensive sheep raising, near livestock farms, and away from urban settlements (Chacabuco A, Cóndor, and Jones). The other four roosting sites were located near, or within urban areas: Villa La Angostura roost is around 2 km away from a rubbish dump; Victoria roost on an island inside Nahuel Huapi National Park (14 km from the dump), and Coihues and Dina Huapi roosts were on trees in the surroundings of villages with these names (9 and 17 km from the dump respectively) (Fig. 1). In 2020, we collected pellets again from two black vultures' communal roosts: one located on an island (de la Guardia Island roost) in the Nahuel Huapi Lake, near the rubbish dump of Villa La Angostura (2 km from the dump) and one in Dina Huapi village, sampled before in 2010 (Fig. 1). For turkey vultures, we collected pellets at two roosting sites in 2010, one of them was on trees in a rural area (Chacabuco B), and the other one was on trees in a town (Chocón, 3 Km from the dump) (Fig. 1). The Chocón roosting site was also sampled in the year 2020. Despite having sampled this roosting site in 2010 and 2020, we did not use this site to compare the increase in plastic debris between years for the turkey vulture due to the low sample size obtained in the year 2020. We analyzed in total 1170 pellets, 187 to Andean condors, 865 belonging to black vultures and 118 to turkey vultures.

To evaluate if the studied vulture species could spread plastic to different environments, we compared the cover of plastic debris (percentage of meso and macroplastics that can be observed with the naked eye) on the ground under two different roosting sites (Dina Huapi and Villa La Angostura) with the cover of plastic in the surrounding area (at 100 m). For this, we randomly placed a quadrat of 1 m^2 to estimate the cover of plastic on the ground in two areas: 27 plots on the ground directly below the communal roost and on the ground 100m away from the roost. We evaluated the cover of plastic debris by detecting the number of plastic items found on the soil within the quadrat and estimating the cover per square meter. Two observers worked together to detect the items of plastic in the quadrats. We registered the potential origin of each item as potentially dispersed by a vulture or not. We considered that plastic was dispersed by a vulture species if they were associated with a fresh or dry structurally intact, or partially broken pellet (Provencher et al., 2019).

Pellets collected were taken to the laboratory to be dried in a stove at 45°C for 48 hours. The most representative elements, such as hairs, bones, and synthetic materials were separated and stored in hermetic bags for each pellet with the aid of a stereoscopic microscope and forceps. This methodology allowed us to detect synthetic materials in a wide range of sizes. We classified plastic items according to Provencher et al. (2017) by its size as microplastics (< 5 mm), mesoplastics (5-20 mm), macroplastics (>20-100 mm), or megaplastic (>100 mm); and by its type as sheet plastics (e.g., plastic bags), threadlike plastic (e.g., rope or netting), foamed synthetics (e.g., polystyrene), hard fragments (unidentifiable objects) and other plastics (e.g., uncommon items such as pieces of balloon rubber, Table 1). Given that plastic elements can be fragmented during the digestive process, we counted the different fragments of the same plastic-type that were present in the same pellet only once (e.g., if a pellet had numerous fragments of polyethylene bags, we counted as it one plastic debris).

2.4 Statistical analysis

To describe the existence of plastic debris in pellets, we computed the frequency of occurrence (hereafter occurrence) of this synthetic material in pellets for each studied species following Provencher et al. (2017). For this, we divided the number of pellets with plastic debris over the total pellets examined multiplied by 100. We also computed the 95% Wilson's score confidence interval of species occurrence using Epitools (http://epitools.ausvet.com.au.).

Then, to compare the presence of plastic debris in pellets (pellets containing or not plastic debris) among the studied species and to evaluate the influence of distance to the rubbish dumps on this presence we performed a logistic regression (binomial distribution) (Gelman and Hill, 2006). We included plastic presence in pellets as a response binomial variable (1 or 0) and the variables species and distance to a rubbish dump as predictors. We assigned (1) to pellets containing plastic debris and (0) to pellets without plastic debris.

To compare the occurrence (as described above) of plastic debris in pellets of black vultures between 2010-2020 we used the Fisher exact test. Finally, we also used the Fisher exact test to evaluate if vultures disperse plastic debris by comparing the plastic dispersed by vultures found on the ground directly under the roost associated with intact, or partially broken pellet, respect to plastic not dispersed by them (the one we found at 100 m from a roost) for two roosting sites. All statistical analyses were performed with R core team (2015) (R Core Team, 2015) and we considered p-values < 0.05 as significant.

3. RESULTS

We found that 17.4 % (203/1170) of the pellets analyzed belonging to the three study species together contained diverse synthetic material. These materials were represented by diverse items including plastic debris, but also other synthetic materials such as paperboard, foil paper, glass, and cloth fragments (Table 1). Out of the synthetic material, 89.2 % corresponded to plastic debris and 10.8 % corresponded to other synthetic materials (Table 1, Fig. 2A, Fig. 3A). The occurrence of plastic debris present in pellets was lower in Andean condors 1.1 % (CI 95%= 0 % - 4 %) and more similar between black vultures 17.3% (CI 95%= 15 % - 20 %) and turkey vultures 24.5 % (CI 95%= 17 % - 33 %) (Table 1, Fig. 2B). For condors, we only found ear tags used for livestock practices, but no other kind of plastic (Fig 3B).

The probability of having plastic debris in pellets was lower in Andean condors compared with black (Estimate (±SE) = 2.238 ± 0.725; Z-value = 3.086; P = 0.002) and turkey vultures (Estimate (±SE) = 1.656 ± 0.778; Z-value = 2.129; P = 0.033). In addition, the probability of plastic debris presence in pellets collected in roosting sites near rubbish dumps was higher than in those collected far away (Estimate (±SE) = -0.062 ± 0.008; Z-value = -7.237; P < 0.001, Fig. 2C). We found plastic debris in pellets up to a distance of 56 km from the nearest rubbish dump (Chacabuco A), and on an island within a National Park (De la Guardia Island) where there is no human presence (Fig. 3C).

Regarding the temporal sampling, we found that occurrence of plastic debris in pellets from black vultures differed between the years 2010 and 2020 (Fisher exact test, CI 95%= 0.30-0.77, OR=0.48, *P*=0.001). Pellets sampled in 2020 showed a higher occurrence of plastic debris compared with pellets sampled in 2010 (Fig. 2D). Finally, plastic debris were only found just below the roost and being part of vultures´ pellets in two communal roosts used by black vultures (plastic ground cover under communal roost: Mean=12.7%, SD=7.68; Mean cover in surroundings, at 100 m from the roost= 0% SD=0) (Fig. 3A-C).

4. DISCUSSION

We found that most synthetic material present in scavengers' pellets from Patagonia was plastic in the form of sheet plastic (polyethylene bags), threadlike plastics, hard plastic fragments, and other plastic material such as balloons. Therefore, they are exposed to this harmful material. We found that black and turkey vultures had a higher probability to possess plastic in their pellets compared with Andean condors, which only consumed cattle ear tags on two occasions. The probability of having plastic debris in the pellets was also negatively related to the distance between open rubbish dumps and the roost location. Moreover, we found an increase in plastic debris in pellets from black vultures between 2010 and 2020. Finally, we showed the vulture species studied may be dispersing plastic from human-impacted sites to natural environments generating involuntary plastic pollution.

The differences in plastic debris found in pellets among the studied species are probably related to their feeding habits and tolerance to humanized sites. While in northwestern Patagonia these three vulture species share food sources represented mainly by wild and domestic ungulates (Ballejo et al., 2018), they differ in their feeding habits. Andean condors tend to avoid anthropic areas to feed whereas black and turkey vultures do not

(Bellati, 2000; Lambertucci et al., 2009a; Plaza and Lambertucci, 2018a). Thus, tolerance and the use of humanized areas influence plastic ingestion in the studied species. Black and turkey vultures have been reported in anthropic areas taking advantage of organic waste in several parts of their distribution range (Augé, 2017; Plaza and Lambertucci, 2018a; Sazima, 2013; Torres-Mura et al., 2015). However, this tolerance could vary according to the geographical area, and probably to food availability. In this sense, Andean condors have been reported feeding in rubbish dumps in central Chile, which in turn influences the occurrence of plastic debris in their pellets collected in communal roosts (Pavez et al., 2019). So, this species is not moving relevant quantities of plastic to natural environments in our study area but may be doing so in other parts of its distribution.

Plastic ingestion by vultures are being increasingly reported worldwide (Augé, 2017; Ballejo and de Santis, 2013; Houston et al., 2007). Other American vultures such as the Critically Endangered California condor (*Gymnogyps californianus*) have been reported ingesting synthetic material of different origins, plastic from rubbish dumps included (Houston et al., 2007; Mee et al., 2007), with waste ingestion being the most important cause of death in nestlings (Rideout et al., 2012). However, the ingestion of plastic has not received much attention compared to other major threats such as poisoning (Plaza et al., 2019) and lead contamination (Plaza and Lambertucci, 2018b). This is concerning given that plastic ingestion could be producing silent impacts on vulture populations (e.g., endocrine disruption; Chen et al., 2019) not yet considered in any region of the world where they occur. Plastic debris may harm vultures through both physical and chemical impacts. Physical impacts are the most obvious ones and include laceration, entanglement, or digestive obstruction (Barnes et al., 2009; Zettler et al., 2013). However, during the plastic degradation process, micro-and nano-plastics are generated and additives used in their manufacture are released (Browne et al., 2011; Rochman et al., 2013). Therefore, vultures may be affected by the ingestion of toxic compounds released during plastic degradation.

Rubbish dumps are one of the most important sites where plastic is discarded and diverse species can use dumps as a food source around the world (Plaza and Lambertucci, 2017). In open dumps, scavengers find large amounts of organic waste together with different synthetic material, especially plastic, that is mixed up. The negative relationship between the presence of plastic in pellets and distance to rubbish dumps we found supports the idea that those places are most probably the source of plastic for vultures. Moreover, the increase in the occurrence of plastic debris in pellets with time we observed for black vultures is worrying. This is probably related to the increase of urbanization and human population in Patagonia with the concomitant increase of plastic pollution through waste disposal (Barnes et al., 2009; Hoornweg et al., 2013). For instance, the human population in Dina Huapi village increased 35 % from 2010 to 2020 (INDEC, 2015 estimations), and the occurrence of plastic in pellets in the communal roost located in this village increased by almost 17%. Most waste deposits in the study area are open dumps with poor waste management and they are overwhelmed due to the great amount of waste that they receive daily. Cities in the study area may also be the source of plastic found, but vultures are not commonly seen foraging inside cities, but in rubbish dumps.

Importantly, our results show that the studied species, especially those that are more tolerant to human-impacted sites (black and turkey vultures), are dispersing plastic debris to the environment (Fig. 4). We found pellets containing plastic debris located far from the nearest rubbish dump (e.g., > 50 km). Vultures are highly mobile species that can travel hundreds of kilometers each day, covering different environments including both humanized and pristine sites (Alarcón and Lambertucci, 2018a). In fact, we observed wing tagged black vultures that routinely feed in a rubbish dump roosting in pristine sites, and black vultures wing tagged in pristine sites visiting a rubbish dump (Plaza and Lambertucci, 2018a; Fig 3D). Moreover, plastic can be moved from dumps within a National Park and even to an island in a large lake without human presence (Fig 3C-D), generating "plastic islands" below vulture communal roosts (Fig. 4). This is concerning particularly in protected areas where management of human waste is already a problem. Additionally, jurisdictional issues impede protected areas administrations to regulate or deter the impact of plastic imported from outside their borders by animals. So inter-jurisdictional work is needed and primarily important in villages surrounding protected areas.

5. CONCLUSIONS

Our results show that plastic ingestion could be an unnoticed problem for vultures that merits more attention, especially for those species that tolerate humanized sites. This work highlights that vultures and probably many other animal species that feed in rubbish dumps can be acting as plastic dispersers, producing plastic pollution in terrestrial and aquatic environments. This is something that has been poorly investigated, and it is particularly relevant in the case of communal roosting animals because they may be generating plastic islands in remote pristine areas with low or no human presence. Therefore, our results call for urgent solutions to reduce the exposure of wildlife to plastic. Mitigation strategies are needed to reduce the potential impacts that plastic could produce on species of conservation concern and the environment. Without the reduction of plastic generation and the improvement of waste management policies the increasing trend of animals consuming and dispersing plastics worldwide will continue.

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7. CONFLICT OF INTEREST

No conflict of interest declared

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Figure 1: Distribution of vulture communal roosts (sampling sites) where pellets were collected (black dots), and rubbish dumps from the area (rubbish icons). Comunal roots: (1) De la Guardia Island; (2) Villa La Angostura, (3) Victoria, (4) Coihues, (5) Dina Huapi, (6) Jones, (7) Chacabuco A, (8) Chacabuco B, (9) Condorerita, (10), Chaqueñita, (11) Pipilcurá, (12) Fragua grande, (13) Buitrera, (14) Cóndor, (15) Chocón.

Figure 2: A) Synthetic material detected in the pellets of the study species. Note the predominance of plastic items. B) Differences in the occurrence of plastic debris discriminated by species (AC=Andean condors, BV=Black vultures and TV=Turkey vultures. C) Probabilities of occurrence of plastic debris in the pellets according to the distance to rubbish dumps and species (grey square=Andean condors, black dots=black vultures and red triangle=turkey vulture). D) Differences in the occurrence of plastic debris in black vultures between the years 2010-2020.

Figure 3: A) Pellet from black vulture with a balloon found in Dina Huapi roost. B) livestock ear tag from an Andean condor pellet. C) Plastic debris (red circle) on the ground below a vulture communal roost associated with disaggregated pellets in de la Guardia Island where there is no human presence. D) Black vulture in La Guardia Island, which was tagged when feeding in a pristine site and then resighted in Villa La Angostura rubbish dump (approximately 60 km away from the tagging site).

Figure 4: Scheme showing the spread of plastic (red arrow) by the studied species from urban to natural environments. The width of the arrows schematically represents the quantities of plastic dispersed by each species. Black silhouette (black vultures), red silhouette (turkey vultures), and grey silhouette (Andean condors).

Table 1: Number of synthetic material found in pellets of the studied species.

Species	Pellets (n)	Sheet plastic	Threadlike plastic	Foamed synthetics	Hard fragments	Other plastic	Other synthetic materials	Total
Andean condor	187	0	0	0	2	0	0	2
Black vulture	865	105	12	0	26	7	20	170
Turkey vulture	118	23	0	1	5	0	2	31
Total	1170	128	12	1	33	7	22	203

AUTHOR CONTRIBUTIONS

Fernando Ballejo: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Original draft; Writing-Review & Editing.

Pablo Plaza: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Original draft; Writing-Review & Editing.

Karina L. Speziale: Conceptualization; Supervision; Investigation; Methodology; Original draft; Writing-Review & Editing.

Agustina P. Lambertucci: Formal analysis and Investigation.

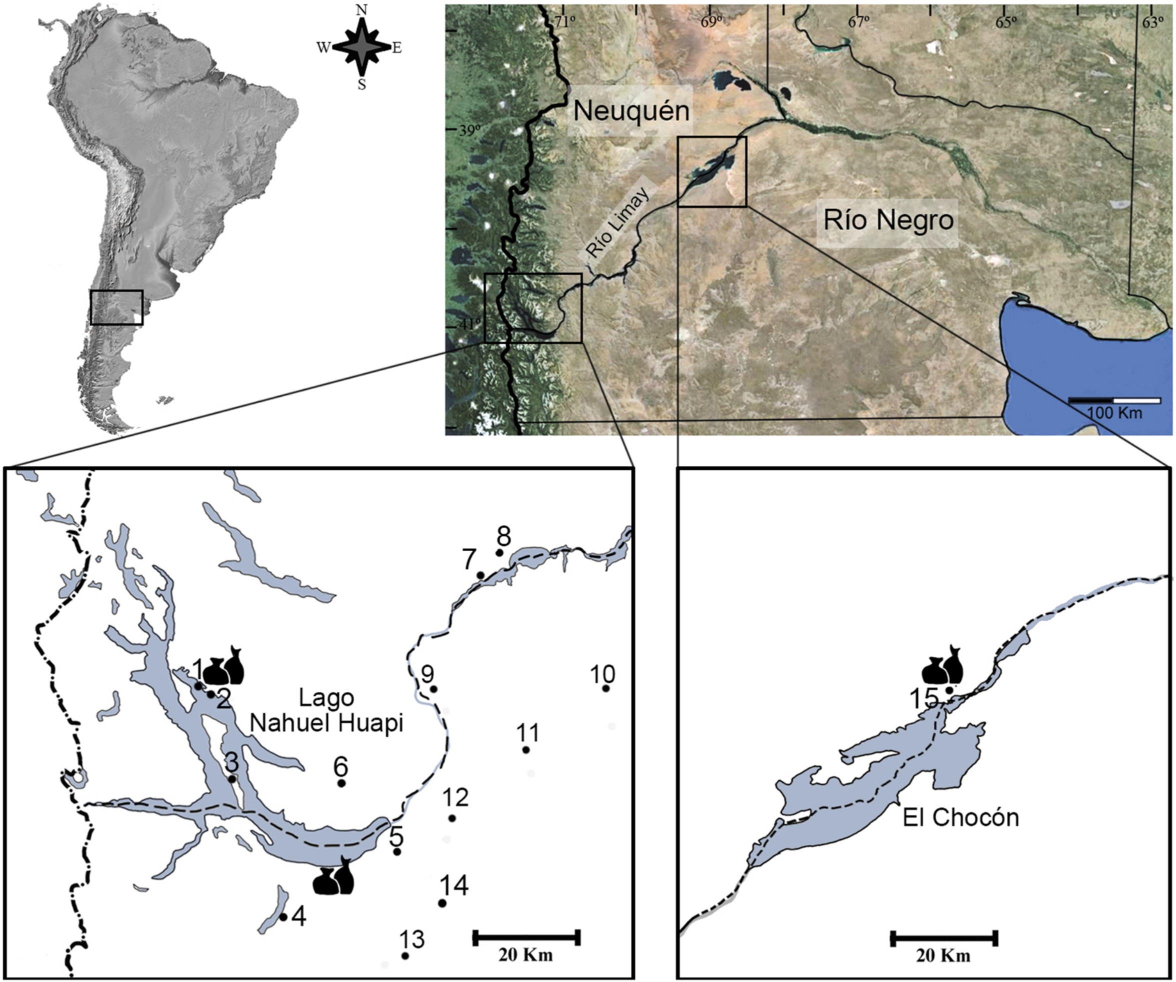
Sergio A. Lambertucci: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Supervision; Validation; Original draft; Writing-Review & Editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Highlights

- Most synthetic material present in pellets of vultures was plastic
- Plastic ingestion varies according to species tolerance and use of humanized sites
- Rubbish dumps are an important source of plastic for vultures
- Vultures spread plastic to distant communal roosts generating “plastic islands”


N
S
W
E
71º
69º
67º
65º
63º
39º
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Neuquén
Río Negro
Río Limay
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Lago
Nahuel Huapi
1
2
3
4
5
6
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8
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11
12
13
14
20 Km
15
El Chocón
20 Km

Figure 1

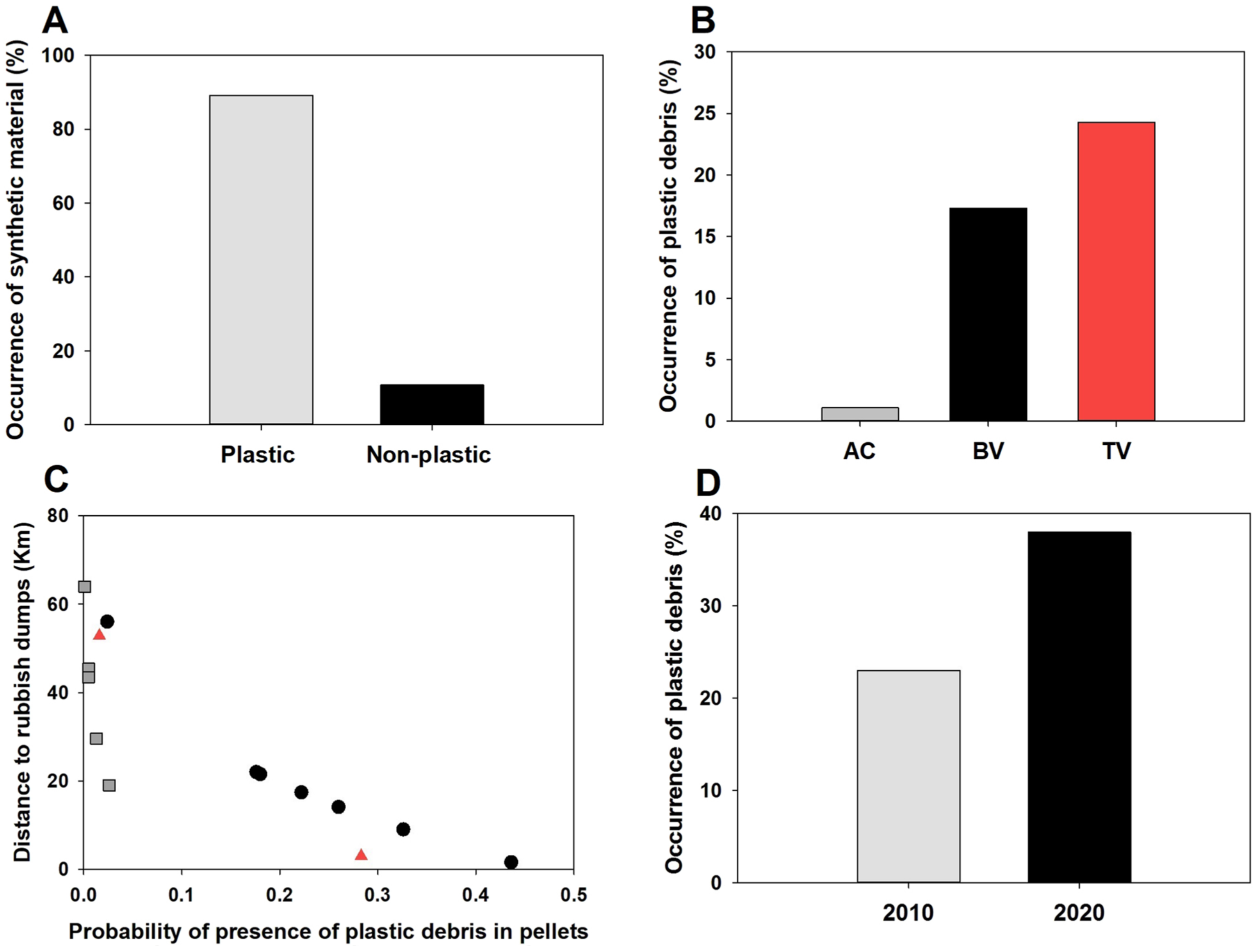
A
Occurrence of synthetic material (%)
100
80
60
40
20
0
Plastic
Non-plastic
B
Occurrence of plastic debris (%)
30
25
20
15
10
5
0
AC
BV
TV
C
Distance to rubbish dumps (Km)
80
60
40
20
0
0.0
0.1
0.2
0.3
0.4
0.5
Probability of presence of plastic debris in pellets
D
Occurrence of plastic debris (%)
40
30
20
10
0
2010
2020

Figure 2

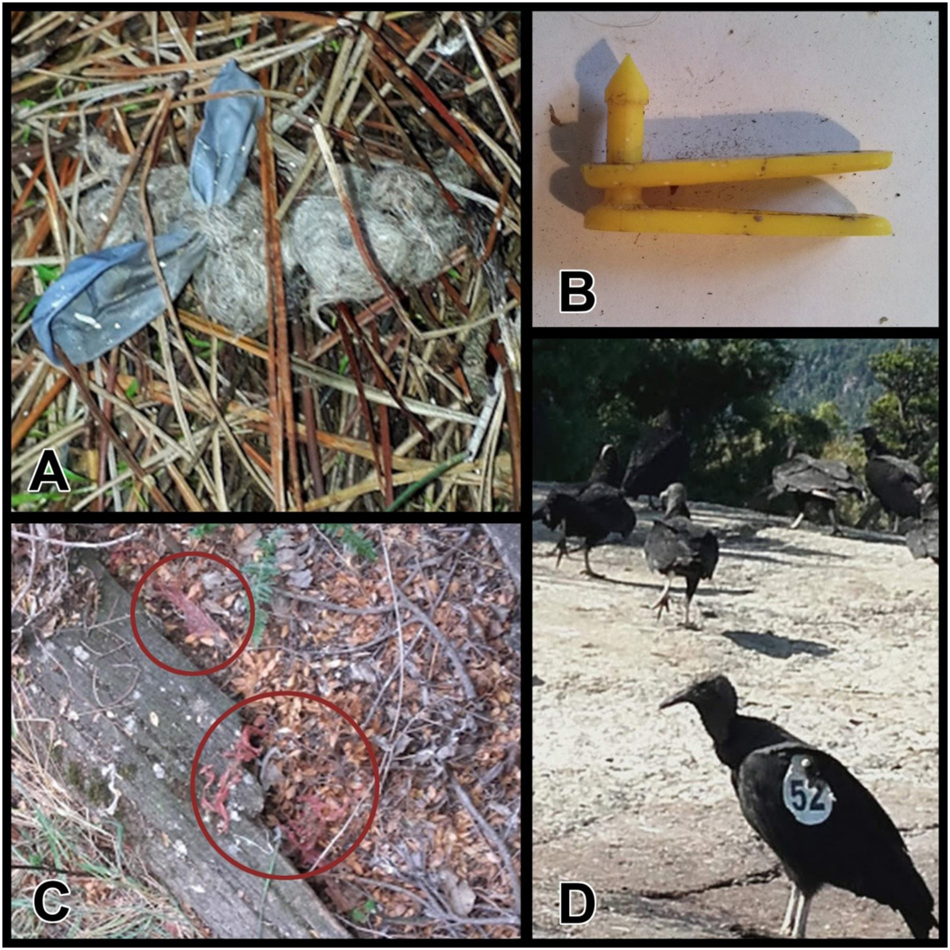

Figure 3

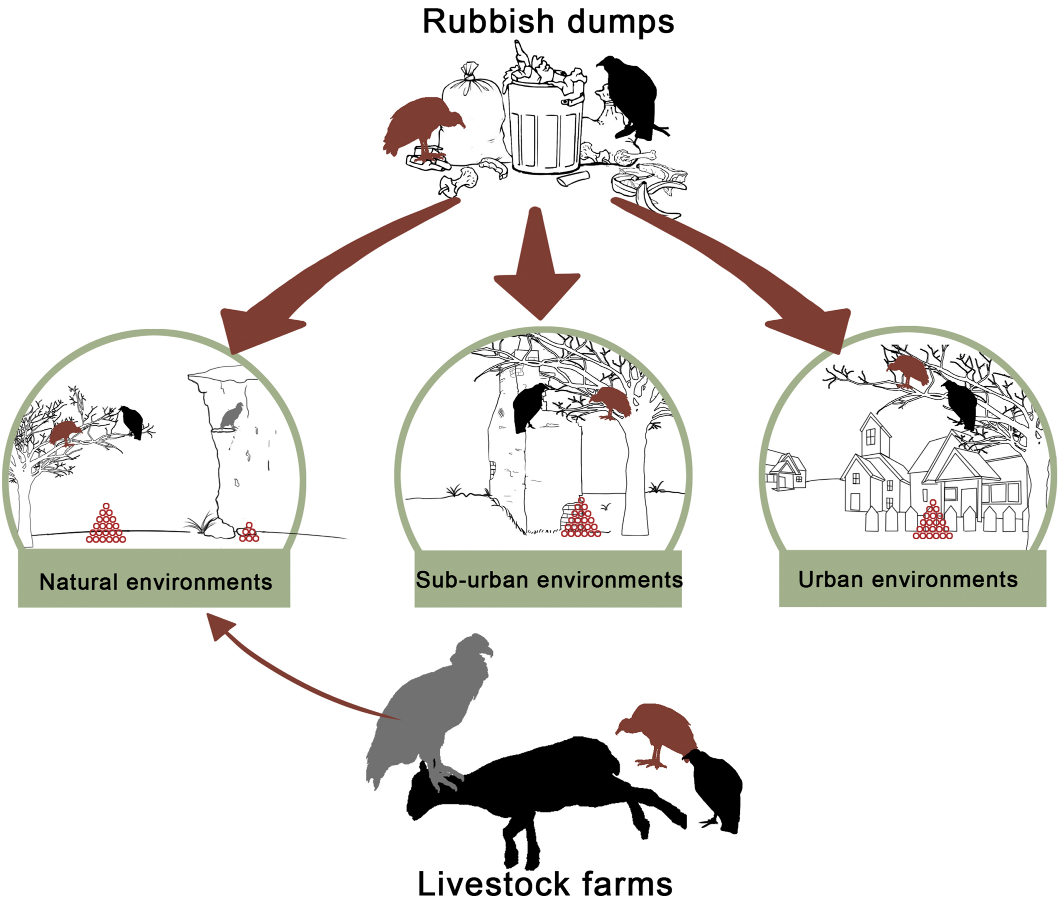
Rubbish dumps
Natural environments
Sub-urban environments
Urban environments
Livestock farms

Figure 4