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High prevalence of parental delivery of plastic debris in Cory's shearwaters (*Calonectris diomedea*)

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ABSTRACT

Plastic ingestion by adult Procellariiformes has been widely recorded, but few studies have evaluated intergenerational transfer. We assessed the prevalence of plastic particles, as well as their basic characteristics, in the gut content of dead Cory's shearwater fledglings stranded by light pollution on Canary Islands. Eighty-three percent of birds were affected, containing on average 8.0 plastic pieces per bird. The average plastic weight per bird was low (2.97 ± 3.97 mg) compared with other petrel species. We found no relationships between plastic loads and body condition or body size, but negative effects may be hidden or delayed. We propose to use the fledglings stranded by light pollution to carry out more precise studies to understand the potential hidden costs of plastic ingestion; and to monitor in a long-term the marine debris to develop management actions for the control of pollution at the marine environment.

Plastics have brought important benefits to humanity such as health, safety, energy savings or material conservation (Andrady and Neal, 2009), but they have also brought concerns about their accumulation in the environment and transfer of chemicals to wildlife and humans (Thompson et al., 2009). Important amounts of plastic debris are widely distributed in all habitats, especially in the oceans, from the sea surface to the bottom (Barnes et al., 2009). This debris negatively affects marine biota, including fishes, turtles, birds and mammals, basically by entanglement and ingestion (Laist, 1987; Derraik, 2002; Gregory, 2009). Plastic ingestion by seabirds has been widely recorded, being Procellariiformes the most affected order (more than 63% of species; Laist, 1997). Despite the voluminous information on ingested plastic debris by adults across the world (e.g. Colabuono et al., 2009; Hyrenbach et al., 2009; van Franeker et al., 2011; Yamashita et al., 2011), the transfer of plastic debris from parents to fledglings has been studied in a limited number of species, mainly from the Pacific Ocean (Hutton et al., 2008; Young et al., 2009; Bester et al., 2010; Carey, 2011; see also Copello et al., 2008).

Monitoring the incidence of plastic ingestion is crucial to assess temporal trends of marine plastic debris and their potential effects on fitness of individuals (Vlietstra and Parga, 2002; van Franeker et al., 2011). Furthermore, studying the gut contents of seabirds is a cost-effective way to monitor plastic debris at sea (Ryan, 2008; Ryan et al., 2009). In this study, we evaluate the prevalence of plastic debris ingested by Cory's shearwater (*Calonectris diomedea*) fledglings in the Canary Islands, North Atlantic Ocean, as well as potential differences between sexes, years and date of fledging. Furthermore, we assess the effect of plastics on the fitness of fledglings measured as body condition and body size indices. Finally, we provide a description of plastic items, including size, mass, color, and type.

During their first flights to the sea, many Cory's shearwater fledglings become disoriented and end up stranded by artificial lights on Tenerife, the largest island of the Canary Islands (Rodríguez

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Table 1
Sources of variation for number, mean length and mass of ingested plastics by Cory's shearwater fledglings after applying general linear models.

Independent variables	Response variables					
	Number of plastics[a]		Mean length of plastics[a]		Ingested plastic mass[a]	
	Estimate ± SE	*P*	Estimate ± SE	*P*	Estimate ± SE	*P*
Intersection	−1.79 ± 3.11	0.629	−1.77 ± 2.09	0.379	−2.88 ± 3.72	0.443
Year		**0.005**		0.165		**0.010**
2009	0.03 ± 0.18		−0.23 ± 0.12		−0.25 ± 0.21	
2010	0.40 ± 0.14		−0.07 ± 0.09		0.29 ± 0.16	
2011	0		0		0	
Sex		0.381		0.747		0.550
Female	0.10 ± 0.11		−0.02 ± 0.08		−0.08 ± 0.13	
Male	0		0		0	
Date of fledging	0.01 ± 0.01	0.500	0.01 ± 0.01	0.211	0.00 ± 0.01	0.806

Significant *P*-values are in bold.
[a] Log-transformed variable.

Fig. 1. Examples of plastic items found in the proventriculus and gizzard of Cory's shearwater (*Calonectris diomedea*) fledglings on Tenerife, Canary Islands.

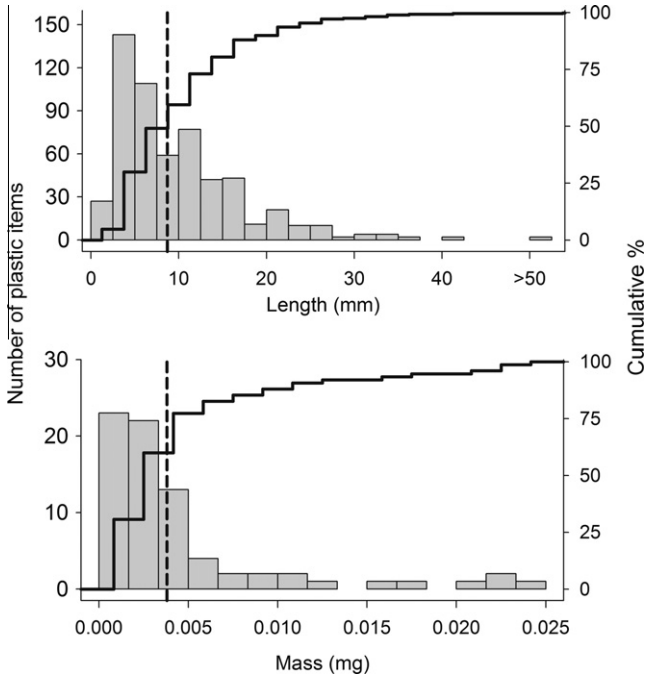

Fig. 2. Size and mass of plastic items ingested by Cory's shearwater (*Calonectris diomedea*) fledglings. Solid and dashed lines represent the cumulative percentage and the mean values, respectively. Mass histogram is based on a subsample of 75 plastic items.

and Rodríguez, 2009). Every year around 1,000 fledglings are collected and recovered during the rescue campaigns carried out by La Tahonilla wildlife rehabilitation center (depending on the local government), NGOs and civil cooperation (although an increase in the number of rescued birds has been recorded since rescue campaigns were established; see Rodríguez et al., 2012a). The majority of them (>95%) are released into the sea, but some fledglings are found dead or agonizing whereas still some others have to be euthanized if they cannot be rehabilitated (Rodríguez and Rodríguez, 2009).

During 2009–2011 fledging seasons (October–November), at least 85 fledglings died or were euthanized by rehabilitation center personnel in Tenerife Island. Corpses were frozen at −20 °C for later analysis. For every bird, date, body mass and six morphometric measurements (wing, tarsus, culmen, bill length at nostril, bill depth and bill depth at nostril) were obtained. The biometrics were taken using a spring balance (±10 g), a ruler (nearest 1 mm) and a digital caliper (±0.01 mm). We conducted a principal component analysis with the six morphometric measurements and the first principal component was used as a body size index (BSI). A body condition index (BCI) was calculated as the standardized residuals of an ordinary least square regression between body mass on body size index (see Rodríguez et al., 2012b for procedures). Birds were molecularly sexed following Rodríguez et al. (2012b) (45 males and 40 females).

After recording the biometrics, we dissected the dead birds to separate the intestine, proventriculus and ventriculus. Gut content was isolated and rinsed in clean water. We looked for plastic items discarding particles shorter than 1 mm because it is a very time consuming task and they contribute little to plastic mass (van Franeker et al., 2011). We categorized plastic debris by type (nylon and irregular particles) and color, and we weighed them using a digital balance (±0.0001 g) and measured its maximum length (nearest 0.5 mm). We also isolated food remains (only cephalopods beaks, the most abundant recognizable food item) and natural debris (wood, feathers and stones), and after being air dried, plastic particles were counted and both particles types, beaks and natural debris, weighed.

We used likelihood ratio tests to evaluate the incidence of plastic ingestion between years and sexes. To test the hypothesis that ingested plastics reduce food intake we evaluated the relationship between plastics and food remains by means of correlations. We applied general linear models to evaluate (1) the differences in the