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Baseline

Incidence of entanglements with marine debris by northern gannets (*Morus bassanus*) in the non-breeding grounds

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ABSTRACT

The quantification of entanglements of megafauna with plastic debris at sea is difficult to assess for several reasons, such as detection and reporting biases. We used standardized vessel based counts to describe and quantify the occurrence of marine debris entanglements in northern gannets *Morus bassanus* at five of its main wintering areas. We observed 34 entangled birds in total, representing 0.93% of all gannets counted ($n = 3672$ individuals). The incidence of entanglements largely varied geographically, being exceptionally high off Mauritania (20.2% of the birds in late spring). Most birds affected were immature (1.88% compared to 0.06% in adults), which in turn represented 52.4% of all the birds. Entanglements in the lower bill mandible were the most frequent, mainly with red-colored plastic objects. Further research is urgently needed to evaluate the impact of entanglements at the population level and its occurrence in other marine species, and to seek potential solutions.

Large amounts of plastic debris are widely distributed across the oceans, from the sea surface to the benthic zone (Pruter, 1987; Barnes et al., 2009; Ryan et al., 2009). These plastics originate from several sources, such as ships, rivers and coastal drainage systems, and they are composed mainly of fishing gear, packaging materials, convenience items, and raw plastics (Pruter, 1987). These remains negatively affect marine birds and other biota by either ingestion or entanglement (Laist, 1987; Derraik, 2002; Gregory, 2009). Whereas the occurrence of plastic ingestion by seabirds has been widely reported even in young individuals which have not reached the sea (e.g. Ryan, 1987; Laist, 1997; Gregory, 2009; Young et al., 2009; Rodríguez et al., 2012), there is little information available on the incidence of seabird entanglements caused by adrift plastic debris (Azzarello and Van Vleet, 1987; Gregory, 2009). This is likely due both to the low detectability of entanglements and to the potential biases in sampling and reporting, which make very difficult to quantify and characterize such a hazard (see review in Laist, 1997). It is necessary to fill this gap, as entanglements pose a potentially serious threat to seabirds, mainly by reducing both their flight ability and their foraging efficiency, thus driving them to long term debilitation and starvation (Derraik, 2002). Of particular concern regarding entanglements are lost fishing gear (often called "ghost gear"), since these fishery remains are very common in the most important fishing areas, which also tend to be important foraging hotspots for seabirds (Tasker et al., 2000; Davoren, 2007).

The northern gannet *Morus bassanus* is a large seabird that nests in densely populated colonies in the Northeast Atlantic at latitudes ranging between 48° and 66°N (Nelson, 2002). It shows delayed sexual maturity, and age-related plumage changes allow easy field ageing of birds up to four years old. Although its general biology has been well studied in the breeding colonies, precise studies of distribution at sea have only been conducted recently (e.g. Hamer et al., 2000; Kubetzki et al., 2009; Votier et al., 2010, 2011a; Fort et al., 2012). An important factor influencing its winter distribution could be fisheries (Kubetzki et al., 2009), as gannets often feed on fishery discards (Camphuysen and Van der Meer, 2005; Votier et al., 2010, 2013).

The most frequent interaction of northern gannets with plastic debris seems to be the entanglement with lost fishing gear used for nest construction. A handful of studies have reported this phenomenon near the breeding grounds, both at sea (where most entanglements took place around the bill; Schrey and Vauk, 1987; Tasker et al., 2000; Camphuysen, 2001) and in the colonies (where feet get frequently entangled with debris used for nest construction; Montevecchi, 1991; Votier et al., 2011b). In this sense, the amount of fishing gear in nests was related to the fishing effort in the foraging ranges around their colonies (Bond et al., 2012). The aim of this contribution is to shed light on the occurrence of entanglements with plastic debris for northern gannets in the wintering areas.

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Data were gathered on the continental shelf waters off Spanish Iberia and Mauritania, and in the Concepción Bank off NE Canary Islands (Fig. 1), coinciding with the main wintering areas of the species (Nelson, 2002; Wanless, 2002; Kubetzki et al., 2009; Fort et al., 2012). Systematic seabird surveys were carried out in these regions within the frame of two EU funded LIFE projects between 2007 and 2010 (Arcos et al., 2009; SEO/BirdLife, 2013; Table 1). Here, six cruises were selected, roughly coinciding with the period of main gannet occurrence (October–June). In all cases, seabird counts were conducted by the same observer (BR).

The surveys consisted on vessel-based transect counts, following Tasker et al. (1984). A 300-m strip-transect band on either one or both sides of the vessel, depending on observation conditions, was used to estimate seabird densities, applying snapshot counts for flying birds (Tasker et al., 1984). Birds outside the transect band were also recorded, but did not contribute to the estimation of densities. For gannets, age class was assessed following Nelson (2002), and allocated to calendar years (Table 2). However, for general statements the term "immature" is used here in a broad sense, i.e. including both first calendar year and sub-adult birds. The presence or absence of plastic entanglements was noted. Birds showing entanglements were considered only once; repetitions were easily avoided as the affected individuals were easily recognizable. We took photographs of the affected individuals, using a Canon 40D camera and a 400 mm f5.6 Canon lens, both for individual identification and for description of the entanglement (type of plastic debris, color and size). As birds were not studied in the hand, we roughly estimated length of the entangled plastic debris by comparing it with culmen length using the pictures. As a reference, we measured the culmen length of seven immature specimens deposited at the zoological collection of the Estación Biológica de Doñana (CSIC), Seville, Spain (mean ± SD = 9.5 ± 0.4 cm, range 8.8–9.9 cm).

Surveys were conducted across 8542 km, covering 4189 km^2 and counting a total of 3672 gannets (Tables 1 and 2). Density and age class composition varied seasonally and geographically, with higher densities off Atlantic Iberia in autumn–winter (Fig. 1). The proportion of immature birds was highest in the areas most distant from the breeding colonies, namely Mauritania and the western Mediterranean, and increased towards the spring.

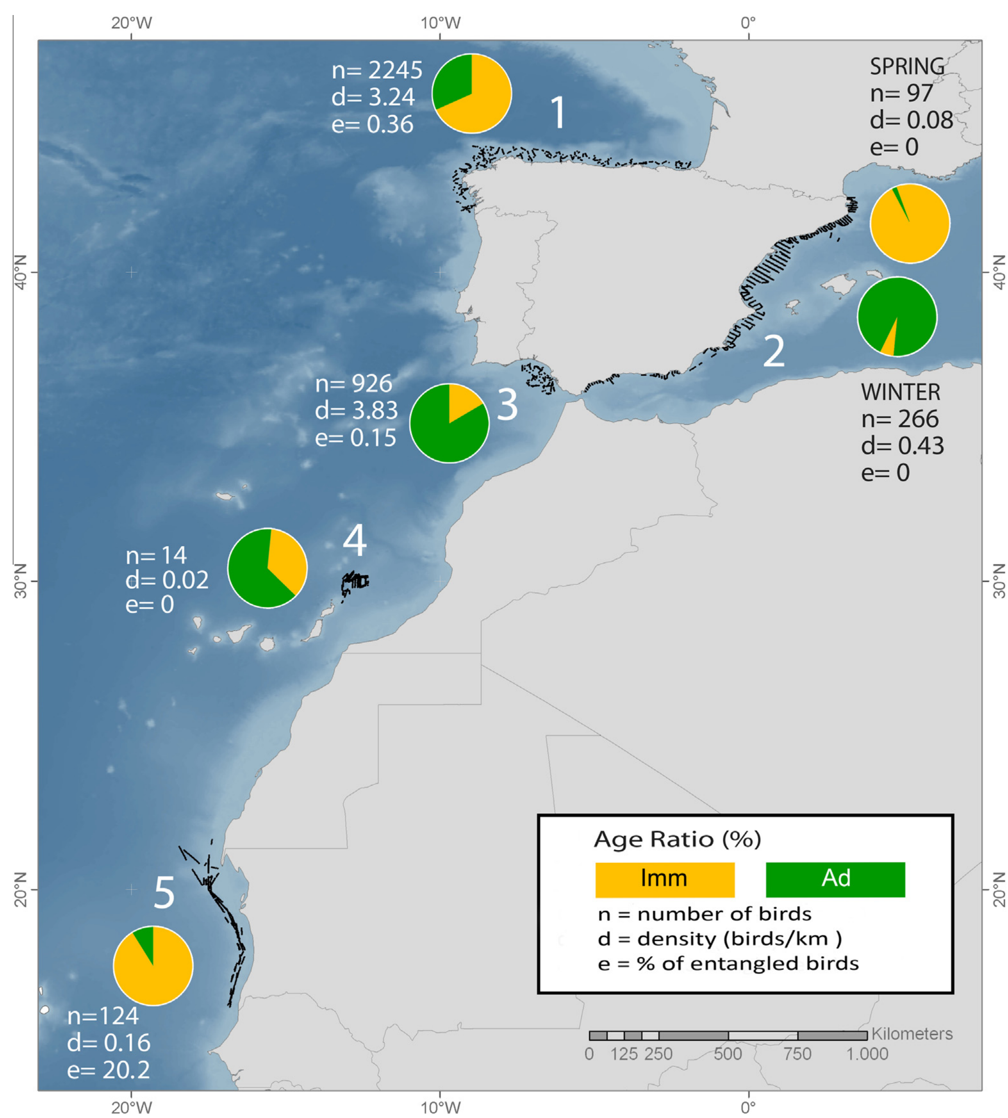

Fig. 1. Map of the study areas where northern gannet *Morus bassanus* surveys were conducted (1 = Cantabrian Sea, 2 = Western Mediterranean, 3 = Gulf of Cádiz, 4 = Eastern Canary Islands, 5 = Mauritanian waters). The black lines indicate the transect locations. The pie charts represent the frequency of occurrence of the age classes (Imm = immature birds of 1–4 calendar year, and Ad = adult birds). For each region, the number of birds counted (*n*), the estimated average density (*d*) and the occurrence of entanglements (*e*, in %) are also shown.

Table 1
Details of the boat survey effort for the five study areas.

Census details	Cantabrian Sea	Mediterranean		Cádiz	Canary Islands	Mauritania	Total
		Spring	Winter				
Month	October	June	December	November	March	June	–
Year	2010	2009	2007	2010	2010	2008	–
Distance (km)	1185	2147	1308	403	1014	2486	8542
Area (km^2)	692	1255	614	242	602	784	4189

Table 2
Age and number (*n*) of northern gannets *Morus bassanus* observed during the present study at the five different wintering areas considered. The number of birds entangled for each age class is also shown, as well as the corresponding percentage (figure within brackets).

Site	1cy		2cy		3cy		4cy		Adult		Total	
	Entangled (%)	*n*	Entangled (%)	*n*	Entangled (%)	*n*	Entangled (%)	*n*	Entangled (%)	*n*	Entangled (%)	*n*
Cantabrian Sea	1 (0.16)	636	1 (0.94)	106	4 (0.70)	570	2 (2.41)	83	0 (0)	647	8 (0.36)	2245[a]
Mediterranean W	0 (0)	3	0 (0)	2	0 (0)	3	0 (0)	7	0 (0)	251	0 (0)	266
Mediterranean S	0 (0)	2	0 (0)	71	0 (0)	21	0 (0)	1	0 (0)	2	0 (0)	97
Gulf of Cádiz	0 (0)	53	0 (0)	5	0 (0)	56	0 (0)	19	1 (0.11)	672	1 (0.15)	926[b]
Canary Islands	0 (0)	0	0 (0)	4	0 (0)	0	0 (0)	1	0 (0)	9	0 (0)	14
Mauritania	0 (0)	0	22 (20.00)	110	3 (100.0)	3	0 (0)	0	0 (0)	11	25 (20.16)	124
Total	1 (0.14)	694	23 (7.72)	298	7 (1.07)	653	2 (1.80)	111	1 (0.06)	1592	34 (0.93)	3672[a,b]

[a] 203 birds were not aged.
[b] 121 birds were not aged.

We recorded 34 observations of entangled birds, representing a minimum of 0.93% of all gannets counted (Table 2). The incidence of entanglements largely varied geographically, being exceptionally high off Mauritania (20.2% of the birds seen in late spring) and much lower off the Cantabrian and Galician coasts (0.36%) and the Gulf of Cádiz (0.15%). No entangled birds were detected in the reported surveys from the Mediterranean Sea and the Canary Islands. Most entangled birds were in their first cycle (1st and 2nd calendar year), and only one adult bird was reported, although 47.6% of the gannets observed were adults (Table 2). Gannets were entangled with different debris, all of them presumably related to lost fishing gear: ropes ($n = 25$; 73.5%), net remains ($n = 5$; 11.8%) and nylon fishing lines ($n = 4$; 14.7%) (Fig. 2). The mean estimated size of these debris was 25.2 ± 21.9 cm, ranging from 4.3 to 89.3 cm. Red objects were the most frequent ($n = 14$), followed by green ($n = 8$), white ($n = 7$) and yellow debris ($n = 1$). All entanglements detected occurred in the bill, predominantly around the lower mandible (28 out of 34 entanglements, Fig. 2). Apparent bill deformation due to entanglements was noted in three individuals, one of them showing the lower bill broken (Fig. 2E).

So far no systematic surveys had attempted to assess the occurrence of plastic entanglements in northern gannets at sea in their wintering grounds. In the present study, almost 1% of the gannets showed entanglements, which should be taken as a minimum value, since some affected birds could have passed unnoticed (if they had small plastic debris or were distant from the vessel). Moreover, non-affected birds could have been counted on repeated occasions, whereas for entangled birds repetitions were carefully excluded, thus leading to a potential underestimation of entanglement rates. In any case, a 1% frequency of entanglement suggests that this is a fairly common phenomenon that could pose a threat to northern gannets. No other seabird species were observed showing entanglements during the reported surveys (49,465 birds belonging to over 30 species in all transect censuses). Although gannets are particularly conspicuous and facilitate the detection of these incidents, these results suggest that the species is particularly sensitive to this threat.

Entanglements mainly affected immature birds (particularly first cycle birds). If so, the impact of entanglements on the population dynamics of the species would be less severe than if adults were more frequently affected, as population growth rate is less sensitive to changes in immature survival compared with adult survival (Weimerskirch, 2002). Given that immature birds were more affected than adults, entanglements are likely related to the fishing experience of birds. It could also play a role the differences in the home range between age classes, adults spending less time (approximately 3 months) in the wintering areas, whereas immature use them also in late spring and summer (Nelson, 2002; Kubetzki et al., 2009). It is also known that northern gannets usually employ synthetic material in nest construction and therefore both adults and chicks can get entangled in the breeding grounds, but mostly around the legs and feet (Montevecchi, 1991; Tasker et al., 2000; Votier et al., 2011b; Bond et al., 2012).

Of particular concern is the exceptionally high frequency of entangled birds reported off Mauritania (over 20%), which is likely one of the main wintering areas of the species (Kubetzki et al., 2009; Fort et al., 2012). Nevertheless, this rate was estimated in late spring, when the bulk of the wintering population has returned to the breeding grounds (Nelson, 2002). Birds remaining in the wintering areas in late spring could be in lower condition than usual, including entangled birds. Another factor that could influence the high rate of entanglements reported in this area is the artisanal local fishery that usually employs low quality or reused fishing gear (Campredon and Cuq, 2001; pers. obs.), producing more plastic waste. It is also possible that the high productivity of this area, and particularly the significant amount of fishery discards produced by the international fishing fleets operating there (Kaczynski and Fluharty, 2002; Alder and Sumaila, 2004; ter Hofstede and Dickey-Collas, 2006), attracts but also favors the survival of these handicapped immature gannets, that could remain concentrated there, compared to other less productive areas (Newton, 2008; Kubetzki et al., 2009).

Entanglements with red objects were more common than white, green or yellow ones. It remains as an open question if red color is actively selected by gannets or if the observed pattern is related to the proportion of colors in lost fishing gear. More precise studies, evaluating the colors employed in fishing gear and nets, the proportion of color in floating fishing debris and the possible selection by gannets upon colors, are necessary. If a positive selection exists, color changes in fishing gear could prove

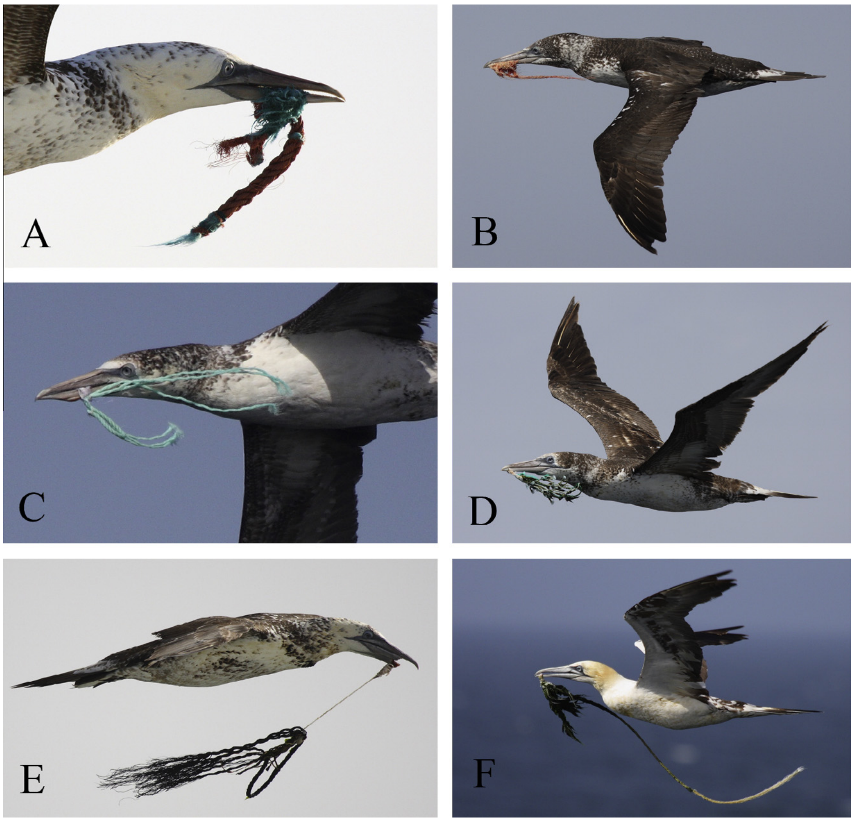

Fig. 2. Examples of northern gannets *Morus bassanus* entangled around the bill observed during this study ((A and B) red ropes; (C and D) net remains, note bill deformation in (C); (E) long white and black rope, note the broken lower bill; (F): long white rope). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

an efficient management measure to reduce the frequency of entanglements.

The "plunge diving" fishing behaviour of the species (Garthe et al., 2000; Nelson, 2002) is likely the cause of the high rate of entanglements. Birds must get entangled either when they dive-bomb directly into adrift plastic objects because confuse them with food or when birds try to catch fish concentrated under adrift objects (Rountree, 1989). Similarly, this behaviour could explain the relatively high incidence of fishing bycatch of gannets reported in some studies (Rogan and Mackey, 2007; ICES, 2008).

In recent decades, surveys of seabirds at sea have increased and currently are regularly carried out within the frame of different scientific projects. We hope that our contribution encourages other researchers to record or, if data are already collected, to publish information similar to that reported here. This would allow to evaluate entanglement trends in northern gannets and other seabird species, and thus to help monitoring the incidence marine plastic pollution using conspicuous biota such as birds (see Ryan et al., 2009). Further research on the causes, impacts at population level and solutions of this type of entanglement are urgently needed (Laist and Liffmann, 2000; Sheavly and Register, 2007). These measures should also include other marine groups where visual assessment is more complex, but that are certainly affected by entanglements, such as turtles, cetaceans and pinnipeds (Laist, 1997; Derraik, 2002; Gregory, 2009).

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